DOUBLE NUMBER

VOL. XXXIX APRIL, 1924 Nos. 3 & 4

JOURNAL

OF THE

Elisha Mitchell Scientific Society

CONTENTS

HISTORICAL SKETCH OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY. *F. P. Venable*.....117

WILLIAM CAIN: MATHEMATICIAN AND ENGINEER. *Archibald Henderson* 123

THE HISTORY AND METHODS OF SCIENCE. *A. H. Patterson*.....131

STRAWBERRY LEAF SCORCH. *F. A. Wolf*.....141

A NEW DOWNY MILDEW ON SOYBEANS. *S. G. Lehman* and *F. A. Wolf* 164

THE GEASTERS OF THE UNITED STATES AND CANADA. *W. C. Coker* 170

ISSUED QUARTERLY
CHAPEL HILL, N. C., U. S. A.

JOURNAL

OF THE

Elisha Mitchell Scientific Society

VOLUME XXXIX
1923-1924

Published for the Society
by the
University of North Carolina Press

CONTENTS

PROCEEDINGS OF THE TWENTY-SECOND ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE 1

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY, OCTOBER 10, 1922, TO MAY 8, 1923 28

DEDIFFERENTIATION IN HYDROIDS AND ASCIDIANS. *H. V. Wilson* .. 40

SOIL TREATMENTS TO OVERCOME THE INJURIOUS EFFECTS OF TOXIC MATERIALS IN EASTERN NORTH CAROLINA SWAMP LANDS. *M. E. Sherwin* 43

CONTRACTILE VACUOLES IN AMOEBAE—FACTORS INFLUENCING THEIR FORMATION AND RATE OF CONTRACTION. *Mary Jane Hogue* 49

VARIATION OF PROTEIN CONTENT OF CORN. PAPER II. *H. B. Arbuckle* and *O. J. Thies, Jr.* 56

DENSITY OF THE CELL SAP OF PLANTS IN RELATION TO ENVIRONMENTAL CONDITIONS. *C. F. Korstian* 63

THE RESEARCH PROGRAM OF THE APPALACHIAN FOREST EXPERIMENT STATION. *E. H. Frothingham* 70

CHEMICAL INDUSTRIES IN NORTH CAROLINA IN 1922. *Frank C. Vilbrandt* 76

DORMANCY IN THE SEEDS OF THE PERSIMMON. *H. L. Blomquist* .. 83

NOTES ON THE TEACHING OF BIOLOGY. *H. L. Blomquist* 86

THE COMMON NAMES OF SOME TREES. *W. W. Ashe* 89

SOME POINTS IN THE BUD DEVELOPMENT OF A SIMPLE ASCIDIAN, *Ecteinascidia turbinata* HERDMAN. *C. Dale Beers* 92

BREEDING HABITS OF LIMNORIA AT BEAUFORT, N. C. *R. E. Coker* .. 95

DEVELOPMENT OF THE FRUIT-BODY OF A NEW PARASITIC RHIZOPOGON. *H. R. Totten* 101

NOTES ON SHRUBS OF THE SOUTHEASTERN STATES. *W. W. Ashe* 110

A NEW SPECIES OF THRAUSTOTHECA. *W. C. Coker* and *J. N. Couch* 112

HISTORICAL SKETCH OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY. *F. P. Venable* 117

WILLIAM CAIN: MATHEMATICIAN AND ENGINEER. *Archibald Henderson.* 123

THE HISTORY AND METHODS OF SCIENCE. *A. H. Patterson* 131

STRAWBERRY LEAF SCORCH. *F. A. Wolf* 141

A NEW DOWNY MILDEW ON SOYBEANS. *S. G. Lehman* and *F. A. Wolf* 164

THE GEASTERS OF THE UNITED STATES AND CANADA. *W. C. Coker* 170

JOURNAL

OF THE

Elisha Mitchell Scientific Society

Volume XXXIX APRIL, 1924 Nos. 3 & 4

HISTORICAL SKETCH OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY

By F. P. Venable

Two score years have passed since the founding of the Elisha Mitchell Scientific Society. It seems appropriate therefore that some account should be given of its aims and the work accomplished during that period.

It may be said that nothing short of the optimism and audacity of youth could have proposed and carried out such a plan. Its founders were young men, scarcely averaging twenty-five years of age, who were connected with the faculty of the University. They were four in number, R. H. Graves, professor of mathematics, J. A. Holmes, professor of biology and geology, W. B. Phillips, chemist in the Agricultural Experiment Station then located at the University, and F. P. Venable, professor of chemistry. They camouflaged their identity and borrowed prestige for their bold adventure by adopting the names Hump, Rump, Mike, and the Blank. These pseudonyms stood respectively for no lesser personages than Sir Humphrey Davy, Count Rumford, Michael Faraday, and an humble unknown. So far as memory serves this latter was identified with the last name given above. Of the four founders he alone has survived the wear and tear of the forty years. He had the honor of being chosen the first President of the society and at the close of his term of office was made Permanent Secretary and held that office for something like three decades. In the mere nature of things in this world of ours nothing can be really permanent, not even a secretary.

Other members of the faculty and some advanced students were invited to join the Society and the President of the University, Dr.

Kemp P. Battle, presided over the first meeting. In selecting a name for the society it was thought appropriate to connect it with the past history of the old university by adopting the name of some former member of the faculty who was known for some scientific achievement. The name of Elisha Mitchell was chosen. Dr. Mitchell had entered the University in 1818 as professor of mathematics. He had taken part in various state surveys, had aided in preparing the first report of a geological survey published by any State in the Union. His name was especially connected with his survey of the mountain region where he found the highest peak east of the Rockies. This was named Mount Mitchell after him and in his last survey of it in 1857 he lost his life. His tragic death made a lasting impression upon the people of the State.

Within ten years Ralph Graves died while in the service of the University. A man of fine scholarly attainments, a profound mathematician, he seemed destined to write his name high among the leaders in his chosen branch of science, but death cut short his career. Joseph A. Holmes after some years became State Geologist and placed the State Geological Survey upon a scientific basis. This office he held for a number of years, ultimately resigning the duties of State Geologist and severing his connecting with the University to connect himself with the U. S. Geological Survey. Through his efforts the U. S. Bureau of Mines was established and he became its first Director. Under his direction the Bureau reached its present position of high importance and splendid service. The pressing and unceasing demands made upon his health and strength brought on the physical breakdown which caused his death. It may be said truly that this important part of the Government's work stands as a lasting monument to his clear vision, high purposes and persuasive power over legislators and congressmen. He has another impressive monument in our Federal Appalachian Park Reserves, which was established largely through his efforts.

William B. Phillips served the University for a brief while as Professor of Technical Chemistry. He was for a year or so Professor of Chemistry in the University of Alabama, then at the University of Texas where he was also State Geologist. Later he was President of the Colorado School of Mines. He was brought back to his geological and metallurgical work in Texas by inducements offered by private corporations and continued to work for them until his death. The

fourth member of the little group, known as The Blank, alone remains in the work which he loved best and with the institution to which he has gladly given the working years of a long life and all the strength that was his.

To fully grasp the difficulties that this group had to face it is well to consider the condition of the University of North Carolina at this period. After lingering for a few years under Reconstruction rule its doors had been closed. They had been re-opened in 1875 just six years before. Its friends contributed a small sum for its rehabilitation. The State appropriated nothing. No direct appropriation had ever been made in the eighty years of the University's existence, either for buildings or maintenance. The University depended mainly upon the interest, $7,500.00, coming from the Federal Land Grant to which was added the small sum received from fees paid by the little band of students.

When this move was made for the founding of a scientific society the total income was less than $20,000. The faculty consisted of ten professors and five assistants or instructors and the student body numbered 210. The outlook, to say the least, could scarcely be considered encouraging but there were at least two motives urging these young men forward. They could not afford to vegetate and lose the productive years of their lives and, perhaps even more compelling, there was a deep devotion to their section of our common country and hope for its future. This was expressed in the first presidential address.

"This society wishes to play this part for the young men of the State, to take them by the hand and lead them in Nature's paths, to arouse in them an ardent purpose to know more of this grand creation and go on learning more and more until desire is stilled at last in the perfect light.

"We can count upon the fingers of our hand the Southern names that will live on the roll of the world's thinkers and workers. We are falling behind in the world's progress and whatever of civilization and knowledge we possess we meekly accept from others. This must not be. It shall not be if we truly love our country.

"It has been the dream of my childhood, it has been the hope of my youth, it is the purpose of my manhood to give my labor and my life to the cause of elevating my beloved South. Even if that life's labor be but slight, if its single influence be small, it is as a drop of

water and many drops make the precious rain that refreshes and strengthens the whole land so that the harvest may be reaped at last."

And so the Elisha Mitchell Society was founded, probably the first society of the kind to be established in connection with any Southern University and among the first of those connected with any university in the country.

The meeting for organization was held Sept. 24, 1883. Dr. Battle, President of the University, was chairman and other members of the faculty were invited to join in the movement. The honor and rather onerous duties of the Presidency were thrust upon the writer of this article, heretofore known as The Blank. On October 1st, 1883, the first regular meeting was held, a constitution adopted and other members added to the roll. Professor J. W. Gore had been elected secretary of the organization meeting. The first meeting for the reading of papers was held on November 10, 1883. So the Society got down to its work.

As financial support was needed for the publication of its journal a number of alumni were asked to become contributing members at a charge of $1.00 per year. The responses were sufficient to cover the cost of the publication. To advance the cause of science in other educational institutions in the State members of their faculties were asked to join with us and a few responded. Also to arouse popular interest some papers of a general popular character were included in the programs of the meetings. Sixty-seven papers were presented at the meetings during the first year. These were fairly distributed over the field of archaeology, botany, chemistry, geology, meteorology, and zoology. Forty-five of these were reports on original work and twenty-three were made by advanced students in the University. Two of these students afterwards studied in Germany. One of them became dean of the medical department of a prominent university and the other a professor of chemistry in a western college and one State chemist was evolved from the group. One technical manufacturer also received his training and inspiration. Lastly one became a member of the faculty of the agricultural college in one of the Southern states.

The first JOURNAL contained 97 pages. By the third year the number of pages had grown to 150. The JOURNAL was offered in exchange for those of other scientific societies. In three years this list of exchanges had grown to 61 coming from nine different coun-

tries and at the close of three more years the exchanges had grown to 274 representing 20 different countries. In this way a very valuable library has been gathered. This collection has been stored in the general library and is the property of the University. It is hoped that some time it will be set apart so as to be directly available for the scientific departments. For a number of years the finances of the University did not admit of its bearing any portion of the expense incurred in publishing the JOURNAL. The publication is now largely financed by the University and the JOURNAL holds a well recognized position among publications of its class. In its fourth year it became a semi-annual publication. Its appearance as a quarterly journal began with the twentieth volume. The JOURNAL is now in its thirty-ninth volume and a total of about 6000 pages have been printed. About eight-ninths of this represents work done in the scientific laboratories of the University by its faculty and students. The high scientific character of the JOURNAL is appreciated in many quarters and it has an increasing list of paid subscribers all over the country. Considerable sums of money have been offered by parties and institutions both in this country and abroad for a full set of the volumes issued but such sets have long ceased to be available.

Largely because of the existence and success of the Society similar organizations have been established in other institutions in the State and a flourishing Academy of Science has been founded of which the JOURNAL is the official organ. It is difficult to form an appreciation of the Society's influence upon the life and work of the University. That it has done much to emphasize the work of the scholar and investigator in contradistinction to that of the hum-drum teacher, content with his daily toll of lectures, may be safely asserted. It has been frankly granted by those who have had opportunity to know through personal observation that the University of North Carolina stands high among the educational institutions of the country for its productive work.

In the beginning there were, of course, some who prophesied failure but such prophets soon abandoned the rather arid task of prophesying and busily sought to emulate the work of the society in their own fields of knowledge. In Historical Science the *James Sprunt Historical Monographs* are now in their twenty-fourth volume, *Studies in Philology* in their twentieth. Clubs for discussions and the

reading of papers have been formed in the departments of medicine and pharmacy and the three divisions of engineering. No claim is made that the Elisha Mitchell Scientific Society is directly responsible for any or all of these but doubtless some credit may be given to it, for with the coming of the society and its vigorous inspiring growth a new spirit was infused into this oldest of state universities as it rose from its broken fortunes.

We would acclaim our cherished society, now fair, fat, and forty, with the time-honored toast, *crescat et floreat.*

CHAPEL HILL, N. C.

WILLIAM CAIN: MATHEMATICIAN AND ENGINEER[1]

By ARCHIBALD HENDERSON

William Cain, born in Hillsboro, N. C., May 14, 1847, had his early education in a private school in Hillsboro and at the Hillsboro Military Academy. In 1866 he was graduated from the North Carolina Military and Polytechnic Institute. After working for a time with W. C. Kerr, State geologist, during which period he made a map of North Carolina, he actively engaged in railroad engineering until 1874, when he accepted a position as Professor of Mathematics and Engineering in the Carolina Military Institute. In 1882 he was elected ranking professor of mathematics at the South Carolina Military Academy. In 1888, he was elected Professor of Mathematics and Engineering at the University of North Carolina, which position he held until his retirement, with an adequate pension in recognition of his long, and distinguished service, in 1920. He received the honorary degrees: LL.D. from the University of South Carolina (1916), and Sc.D. from the University of North Carolina (1920). In 1923 the American Society of Civil Engineers presented him with the J. James R. Croes medal for his paper: "The Circular Arch Under Normal Loads." He is a member of the American Mathematical Society, a Fellow of the American Association for the Advancement of Science, and a member of the American Society of Civil Engineers. In the last named, he has been conspicuously active for many years, as the index of the *Transactions* of the society amply testifies; and he was a Director of the society from 1912 to 1914.

Professor Cain's scientific publications date from the year 1874, when his paper "Uniform Cross-Section and T Abutments" appeared in *Van Nostrand's Engineering Magazine* (November)[2]. In his paper on "Earth Pressure," V. N. E. M., Feb. 1882, he showed that all of

[1] The present sketch deals exclusively with William Cain's work as a scientist. An adequate biographical sketch of him, by J. G. deR. Hamilton, is found in *Biographical History of North Carolina*, vi.

[2] The journals in which Cain's papers have appeared are: *Van Nostrand's Engineering Magazine, Engineering News, Proceedings American Society of Civil Engineers, Transactions American Society of Civil Engineers, Journal of the Franklin Institute, Elisha Mitchell Scientific Society, Science.* The references are usually of the *Transactions* A. S. C. E., as the papers in the *Proceedings* with discussions and author's closure are republished in the *Transactions.*

the experiments given by Sir Benjamin Baker in his notable paper on "The Actual Lateral Pressure of Earthwork," at least in cases where the backing was sand, nearly devoid of cohesion, could be reconciled with theory by rejecting the "ancient" theory used by Baker and adopting the "wall-friction" theory in which the friction of the earth on the wall is considered. Cain's paper, together with his contentions embodied in his discussion of Bell's paper (Proc. Inst. C. E., London, 1915), have never been satisfactorily answered. In his "Retaining Walls," V. N. E. M., April, 1880, he discussed from a broad standpoint, especially with reference to practical applications, Weyranch's theory, which he presented in a simplified form. In his paper, "Trusses with Superfluous Members," V. N. E. M., October, 1882, there was presented for the first time to American readers the theory of trusses with "superfluous" (or "redundant") members, for the first time giving a correct analysis of trestle piers on trestles, where wind forces are included.[3] In "Positions of Live Loads Giving Maximum Strains for Single-Intersection Trusses," V. N. E. M., March, 1885, a thorough discussion of this subject, about which little had then been written, was given; and the method used in this paper furnished the basis for that given in Cain's book: "Maximum Stresses in Framed Bridges," second edition.

An important contribution to engineering practice was the development of the formula known as "Cain's Formula," sometimes as the "Cain-Launhart Formula." This is found in Cain's historic paper, "Unit Stresses," E. N., July 16, 23, August 20, September 3, 1887.[4] Cain modified Launhart's formula to allow for impact. The modified formula was at once adopted by the Pennsylvania Railroad Company; and it has since been extensively used, having for example been adopted in his specifications by Joseph M. Wilson, Chief Engineer of the Pennsylvania Railroad Company. In "Theory of Long Columns," J. F. I., July, 1887, Cain presented the more refined theory of Bresse. In "High Masonry Dams," E. N., June 23, 1888, he takes up the design of a very high dam; and when a new body of engineers took hold of the design of the Quaker-Bridge dam, 265 feet high, his

[3] In this paper the interesting conclusions of M. Maurice Levy are demonstrated in as simple a manner as possible, the theory being illustrated with a number of examples worked out in detail.

[4] This subject had been previously presented by Cain, in briefer form but with many applications, in V. N. E. M. and in "Maximum Stresses in Framed Bridges," 1878 (Van Nostrand's Science Series, No. 38).

ideas were utilized in a beautiful new design, far superior to the original design of Fteley.[5] An original discussion of a complicated subject, "Portal Bracing," E. N., July 13, 1889, gives results such as are used to-day.

In 1891, in his "Stresses in Elastic Systems by the Method of Least Work," *Transactions*, xxiv, April, Cain first introduced to American engineers the method of Castigliano as embodied in his "Systèms Élastiques" (Turin, 1879). Cain herein gave original demonstrations of the theorem of least work for framed structures with "redundant" members, by use of the method of virtual work, with applications. In his paper, "Theory of the Ideal Column," *Transactions*, xxxix, 1898, he deduces Euler's formula, showing that this corresponds to incipient bending of the column; and furthermore shows that a very small increase to a load, as given by Euler's formula, will lead, not simply to a negligible bending, but to a considerable deflection, producing actual rupture due to the large stresses induced in the outside fibers.[6] In his "Theory of the Spherical or Conical Dome of Metal on Reinforced Concrete," *Transactions*, lv, 1905, are found complete analytical and graphical methods for the spherical and conical dome, elasticity being disregarded. This paper was particularly commended by English engineers. In "Stresses in Masonry Dams," *Transactions*, lxiv (1909), he takes up a particular dam 200 feet high, and determines the stresses at this depth, the dam having both faces battered. The method is general and applies for any depth; but it requires elaborate and laborious computations. In a recent work by Morrison and Brodie, "High Masonry Dam Design," the authors quote the whole "Appendix" of Cain's paper and give the bare essentials of the general method of finding stresses at a given depth on any plane. In 1911, he published a most important and elaborate paper, "Experiments on Retaining Walls and Pressures on Tunnels," *Transactions* lxxii, in which for the first time cohesion in earth is included, to reconcile the carefully conducted experiments of Leygue on small models with theory. Also a complete graphical treatment of pressures in earth endowed with

[5] It is to be regretted that, years afterward, Fteley again became chief engineer and built after his original design, ignoring the influences considered by Cain, *viz.*, the forces due to the expansion of ice, wind and wave action, and earthquakes. No high dam in northern latitudes has since been built which wholly ignores such influences.

[6] This paper, which constitutes a complete presentation of the theory of the "Ideal Column" for both central and eccentric loading, has been heartily commended by Professor J. B. Johnson, and by Chapman in "The Strength of the Ideal Column," Proc. Inst. C. E. (London), cxcvii, Session 1913-4, Part III.

both friction and cohesion is given for the first time. Following the publication of H. A. Sewall's "A Shortened Method of Arch Computation," *Transactions*, lxxvi (1913), Cain published one month later in the *Proceedings* the demonstration of a still shorter method, with applications to the arch treated in the text, and furthermore gave a demonstration omitted by Sewall himself, of Sewall's method. In 1914-5, he presented two exhaustive papers, "Stresses in Wedge-Shaped Reinforced Concrete Beams," *Transactions*, lxxvii and lxxviii. The subject does not admit of an exact solution; and two approximate solutions are given throughout for flexural, bond and shearing stresses, and the results compared with each other and with those from the experiments on rubber and plasticine dams. In the paper, "Coefficients of Cohesion," *Transactions*, 1916, all experiments available are given and shown to agree with Coulomb's hypothesis. The need for extensive experimentation is herein pointed out and apparatus in view criticised. On the appearance of this article, the Sub-Committee on Soil Pressures, etc., American Society of Civil Engineers, offered to undertake this work at the United States Bureau of Standards Laboratory, Pittsburg, Pa.

The following papers and monographs, dealing with mathematical and engineering problems, are given only by title: "Sanitary Engineering," 3rd edition, North Carolina Board of Health, 1885; "Brief Demonstration of the Method of Least Work," *E. M. Sci. J.*, viii, 1891; "The Transition Curve," *Transactions*, xxvi, 1892; "On the Fundamental Principles of the Differential Calculus," *E. M. Sci. J.*, ix, Part I, 1892; "Road Bulletin," *North Carolina Geological Survey*, 1893; "The Stone Arch," *E. M. Sci. J.*, x, 1893; "Exact Computation of Stresses in a Queen-Post Truss," *E. M. Sci. J.*, xiii, Part II, 1896; "A New Method of Laying Out Grades for Sewers by Aid of the Transit," *E. M. Sci. J.*, 1901; "Note on the Algebraic Form $\frac{0}{0}$," *E. M. Sci. J.*, xix, Part I, 1903; "Imaginary Roots of a Cubic," *E. M. Sci. J.*, xix, Part II, 1903; "Grain Pressures in Deep Bins," *E. N.*, May 12, 1904; "Crown Thickness of Masonry Arches," *E. N.*, October and November 17, 1904; "The Teaching of Elementary Dynamics," *Science*, July 7, 1916. A number of articles on arches, stresses in bridges, retaining walls, algebra and geometry, appeared in *Van Nostrand's Engineering Magazine;* and these were at once published in book form in Van Nostrand's *Science Series*, with the following original titles: No. 12, "A Practical Theory of Voussoir

Arches," 1874; No. 38, "Maximum Stresses in Framed Bridges," 1878; No. 42, Voussoir Arches Applied to Stone Bridges, Tunnels, Domes, and Groined Arches," 1879; No. 48, "Theory of Solid and Braced Elastic Arches," 1879; No. 73, "Symbolic Algebra and Notes on Geometry," 1884. In 1888, at Mr. Van Nostrand's request, Cain "revised" Arthur Jacob's "Practical Designing of Retaining Walls," doing it so thoroughly that he retained from Jacob's book only one figure! Eventually, Jacob's name as author was displaced by that of Cain; and the book has passed through many editions.

Concerning arches, it must be remembered that in 1874, the best known theories of masonry arches were those of Scheffler and Rankine. In *Science Series* No. 12, Cain utilized Scheffler's method for drawing pressure lines for *incompressible* voussoirs, modifying it by requiring the pressure polygon to cut the corresponding joints within the "middle third" of the arch ring, to allow somewhat for the elastic yielding of the arch. The book contains a discussion of a great number of experiments made by Cain upon wooden arches, at the limit of stability, showing the agreement with theory. It also contains a complete analysis of a stone arch of symmetrical and unsymmetrical loading and also a discussion relating to a viaduct of three spans, including the piers and abutments. Professor Plympton, editor *Van Nostrand's Engineering Magazine*, stated that the engineers of the great East River Bridge used the theory of this book in the design of the arches constituting the approaches to the suspension bridge, finding it the most practical of any existing theory.[7]

In *Science Series*, No. 42, first edition, 1879, an advance is made in the treatment of the stone bridge by considering the elasticity of the material, but the theory of the "elastic arch" is not yet applied in a precise manner. This volume contains much new material on the "barrel" or common arch, on tunnel arches, groined and cloistered arches and domes. A new edition, 1901, bore the title "Theory of Steel-Concrete Arches and of Vaulted Structures." Herein was given, for the first time in either the United States or in Europe a complete, practical method for dealing with the reinforced arch of variable section by the elastic theory, the method applying also to the non-reinforced or stone arch by omitting consideration of the steel reinforcement. It was at once utilized by engineers, and

[7] The title of the second edition (1893) is changed to "Theory of Voussoir Arches." The work is very extensively revised and enlarged.

construction of re-inforced concrete arches was begun on a grand scale. The book was used as a standard text at the leading technical schools.[8]

Cain's "Theory of Solid and Braced Elastic Arches" represents an attempt at an advance in the theory of the elastic arch, consequent upon the inspiration received from Professor H. T. Eddy's "New Constructions in Graphical Statics." Cain gave a clear demonstration of the theory involved, for *any* style of arch, loaded in any manner; and improved on Eddy by propounding a correct theory of temperature stresses. After some years, engineers saw the possibilities in reinforced concrete arches and several wrote to Cain relative to the application of the theory of the elastic arch. Mr. Edwin Thacher, who in recent years has built thousands of such arches, received a great deal of assistance from Cain, who freely gave his improved methods their publication in *Science Series*, No. 42, second edition (1901). As the result of persistent inquiries, Cain's interest in the subject was again excited, and a practical treatment of the most complicated case was attempted. This was a memorable contribution to engineering practice on Cain's part, and due credit for the theory was always given him by Thacher.[9]

When a second edition of No. 48 was called for in 1909, Cain derived a simpler method of treatment, leading not only to graphical but to analytic methods of solution. It was applied in great detail to an arch with a uniform moving load; also to an arch with single loads. A résumé of operations was also given, so that the computer had only to go through certain mechanical operations in order to effect a solution. The two books on reinforced arches, Nos. 42 and 48, have been repeatedly cited as authoritative in technical journals; and the methods set fourth therein have been employed in the design of a number of bridges.[10] The distinguished English engineer, Marsh, paid Professor Cain a high compliment by publishing Cain's arch theory, with Cain's permission, in Marsh's extended work on "Reinforced Concrete" (London, 1904).

[8] In 1905 the fourth edition contained the treatment of spherical and conical domes, published in *Transactions*, lv., same year. In 1909 the method, as a practical method, was improved and simplified.

[9] Because Thacher anticipated, more or less, the methods of No. 42, 2nd edition, as given him by Cain, some engineers have given Thacher perhaps undue credit, by using the phrase "Cain-Thacher Method."

[10] In his "Specifications," 1908, Watson recommends these books to the practical engineer.

In No. 38, "Maximum Stresses in Framed Bridges," Cain gives full treatment of the usual type of trusses. The subject of most economical height of trusses is elaborately discussed. The "unit-stresses" throughout are computed by the "Cain-Launhart formula," which gives satisfactory results in practice. The second edition of this work (1897) is an entirely new work, giving in brief compass but in great detail the method of computing maximum stresses in bridge members for both uniform and wheel loads. The book was highly commended by engineers, Professor Mansfield Merriman, for example, saying: "You have certainly put into small space, in a very clear and thorough manner, all the essential elements of the subject as far as simple trusses are concerned." Another book in this series, No. 73, "Symbolic Algebra on the Algebra of Algebraic Numbers, together with critical notes on the Methods of Reasoning Employed in Geometry," 1884, embodies sound ideas concerning the treatment of negative numbers, "lost" and "strange" solutions in analysis, and other topics, being based in part upon Duhamel's "Science de Raisonnement." A useful text-book, written with Professor Cain's habitual lucidity, is a "Brief Course in the Calculus," Van Nostrand Co., New York, 1st edn., 1905.

The results of many of his published papers and a wealth of additional research are incorporated in Cain's epochal work, "Earth Pressure, Retaining Walls and Bins" (John Wiley and Sons, New York, (1916). The contributions to the subject made by this subject are set fourth in full in my extended review of the book in the ELISHA MITCHELL SCIENTIFIC JOURNAL. Suffice it here to state that Cain greatly improved on the derivation of the fundamental formulas as given by Résal in his "Pousseé des Terres," volume II: "Terres Cohérentes;" and by using Mohr's "circular diagram of stress," he discovered not only the simplest, theoretically, but the best practical, solution for the general case sloping at any angle. The treatment of coherent earth (chapter V) is the first and only treatment of this subject in English; and while totally different from Résal's treatment, leads to the same results. It is clearly proven that the Rankine method is strictly inapplicable to finding the earth pressure against a retaining wall except in certain cases. Cain considers the case when the wall has a plane interior surface and is lubricated with water from rains, making out all the tables for thickness of the various types of retaining walls. This work contains the only treat-

ment of the important practical subject of the "limiting plane" ever given. The results of experiments of retaining walls, given in this book, all agree with the theory of earth pressure, wall friction included, advocated by Cain for more than three decades, and do not agree with the Rankine theory, so blindly followed by nearly all engineers.

Professor Cain is one of the most distinguished engineers, on the score of original theoretical investigations which have been approved in practice, this country has ever produced. The range of his researches is fully exhibited in the present sketch. As an investigation in engineering theory, whose ideas always rest upon a solid practical basis, William Cain is held in highest regard, not only by the engineering profession in this country, but also by leading engineers all over the world.

CHAPEL HILL, N. C.

THE HISTORY AND METHODS OF SCIENCE*

By Andrew H. Patterson

The word Science is one of the most popular words of the day. It seems to give a flavor of dignity and up-to-date-ness to whatever it is used to describe. We have Natural Science, Social Science, Christian Science, the Science of Theology, of Politics, of Astrology, of Mathematics, of Agriculture, of History and half a hundred others. Now it is quite clear that the word "Science" cannot have the same meaning when applied to all these subjects, and so when I begin to speak of the History and Methods of Science it is desirable to give first a definition of what we really mean by the word Science in this connection.

This is not an easy task, but perhaps as good a definition as any might be: "Science is a body of knowledge obtained by observation and experiment, ordered and amplified by study and reflection, and put into usable form for the construction and testing of theories."

Several points must be emphasized;—first and foremost, Science is a search for truth; second, this search is conducted by the patient gathering of facts, and the building of theories on those facts; third, these theories must be tested by every means which man can devise, in order that every possibility of error may be avoided.

So important is this matter of theorizing about facts that one author defines Science as the theories which men hold regarding the truth of everything we see in the Universe.

Just here is where Science is most misunderstood. Many people sneer at "theories," as though they were something unworthy. As a matter of fact, they are absolutely indispensable in the search for truth, and little or no progress can be made without them. They are tools with which we dig our way further into the mass of ignorance which surrounds us.

The use of a theory is two-fold;—to *explain* the relations between facts already ascertained, and to *prophesy* other facts and relations which may be found when looked for. A theory provides us with a working basis,—a point from which we may take off in the further search for truth in the particular realm under investigation.

* Address delivered at the opening of the new Physics Building at the University of Chattanooga, April 26, 1923.

If a theory can explain all known facts about a certain matter, it has begun well, and may be regarded as *possibly* true; if it prophesies other facts which are found when looked for, the theory has acquired more dignity and credibility and may be regarded as *probably* true. If it then stands the test of criticism and experiment for many years, it rises to the rank of a law of Science, and is considered as true for all practical purposes. There may be no way of proving it beyond the shadow of a doubt, but according to the view of the philosophy known as pragmatism if a theory *works*, it is to be considered true, unless proved otherwise.

Thousands of theories have been tested and found wanting, and they have been scrapped without hesitation and without regret, because the scientist does not want to lose one moment in the pursuit of a false trail. Many theories may "explain" things already found out, but few theories can prophesy things to be found when looked for. In the early days of the dawning of science, the explanations given for the phenomena of Nature were simple and childlike, though sometimes highly poetic. The sun was the flaming chariot of the Sun-god traveling across the sky; the lightning was a thunderbolt flung from the hand of an angry deity; comets were portents of evil, to warn or punish men, and so on.

Such crude theories "explained" things after a fashion, but did not and could not measure up to the more important function of a theory,—that of prophecy. The theories of Astrology did indeed attempt to prophesy the future of individuals as written in the stars, and because they failed to do so truly, Astrology has long ago been discredited and discarded.

Compare these old theories with some modern ones. Halley, in 1682, discarded the old view of comets, and formulated a new one, according to which he prophesied that the comet of 1682 would reappear in 1759, which it did, and since then Halley's comet, as we call it, has twice come back on predicted schedule time.

On account of the behavior of the planet Uranus, astronomers formed the theory that an unknown planet existed out beyond Uranus, and Leverrier in 1846 sent his confident message to his friend Galle at Berlin bidding him turn his telescope to a certain point in the sky and he would there see a new planet. Galle did so, and the discovery of Neptune was the result.

Because of some peculiarities in the motion of Sirius, the theory was propounded that the great star is accompanied by a "dark attendant," or cooled-off star, the orbit of which was predicted from observations on Sirius. For many years the existence of this dark attendant was not confirmed, but finally while testing a new telescope at Cambridgeport one of the Clarks discovered the looked-for star in the exact position which had been predicted.

In 1868 Sir Norman Lockyer noticed a dark line in the solar spectrum which did not correspond in position with any bright line in any of the spectra of the known elements. He ascribed it to an unknown element in the sun, and named this supposed element helium, the sun-element. We accepted Lockyer's theory, because of our confidence in the principles of spectrum analysis, but we were never able to confirm it by finding helium on the earth until after many years' search, when we discovered that helium is a constituent of our own atmosphere, and that while groping for it all these years we had been breathing it all the while!

Another fine example of the prophetic value of a theory is the mathematical investigation of the motion of a gyroscope. After the equations had been derived, it was discovered that there should be, theoretically, a turning moment impressed on the gyroscope by the revolution of the earth which would make it turn until its axis pointed to the north star. This effect is so small that for a long time it could not be used, until finally a heavy wheel, delicately poised, was rotated at tremendous speed, and the effect predicted was shown to exist. This forms the basis for the new gyro-compass, which is used on all the big warships and merchant ships of the world. Incidentally, it gives convincing evidence of the rotation of our earth on its axis, which, however, we already knew.

The last example I shall give of scientific prophecy is the Einstein principle of Relativity. When Einstein was asked to give practical proof of the truth of his theory, he first instanced the matter of the precession of the perihelion point of the orbit of Mercury. The amount observed is about seven per cent in excess of that predicted by Newton's mechanics, and in exact agreement with Einstein's formulas. But this was not prophecy,—Einstein knew the answer before developing his formulas, and it was at least possible that the formulas were developed to fit the answer.

So Einstein next gave a test of pure propheey. It was in 1917 that he predicted that during the solar eclipse in May, 1919, two years later, the light from certain stars would be found to be deflected one and three-quarters seconds of arc from its straight path. This was more than twice as much as was to be expected on the basis of Newton's work. Of course Einstein was shut up in Germany by the war, and could not test the propheey himself, but the English sent out two expeditions, one to Brazil and one to Africa, and both confirmed the correctness of Einstein's propheey. This was the reason why Einstein's name suddenly blazed into fame,—his theory had met the test, and had prophesied true things. Last September the same test was applied in the case of another eclipse, and the result was a second triumph for Einstein's views.

But not all theories have fared so well as those I have mentioned. Any man has a right to propose a theory, and to bring forward evidence to support it;—the world then has a right to test the theory and make up its verdict as to whether the theory has been sustained by the facts and the evidence. The majority of theories lose out eventually,—some of them after having been held for many years,—the phlogiston theory in chemistry, for example.

But if the theory has enabled us to go forward to new truth, it matters little whether it itself finally wins out or not. In this sense theories are but scaffolding which we use to build the edifice of solid truth. As each story rises higher, the old scaffolding may be torn away, and the new adjusted for the next flight.

So our theories are continually being modified and renewed, while the search for truth goes steadily on.

The principal way to verify theories is by laboratory experimentation and research. Hence the tremendous importance of laboratory work, and training in methods of measurement and in ways of avoiding error.

When Science first arose, and where, we do not know. Engineering and certain branches of astronomical knowledge had already reached a great height in Egypt and Babylonia at an early date, and many intelligent theories were developed among the Greeks, such as the heliocentric theory of Aristarchus, which preceded that of Copernicus by about two thousand years. But these theories lacked the means of verification, and were mixed up with all kinds of false theories and superstitions, such as those of Astrology, the Black Art, Alchemy, and so on.

Archimedes was a great experimenter, but his followers did not continue the laboratory method, and it was not until Roger Bacon and Galileo appeared that the modern system of laboratory research was started on its marvelous career.

Thus it happens that in the last century Science has made more real progress than in all the years before that time. The Greeks were wonderful in purely intellectual fields, such as philosophy, mathematics, logic, rhetoric, but they were unable to test their theories rigidly, and it must be emphasized again that the ability to test theories, so as to separate the true from the false, is one of the conditions of progress in truth-seeking.

Here is where the necessity for accurate apparatus comes in, and such apparatus is very expensive. But it is absolutely necessary, in order to test our sense perceptions,—which are often untrustworthy,—and enable us to avoid error. The search for truth by scientific methods imperatively demands an open mind, an alert brain, patient research, a well fitted-out laboratory, and instruments of precision.

With these things scientific research and invention have transformed the world we live in. The once dread thunderbolts of Jupiter now peacefully illuminate the streets of ancient Athens and ancient Rome. We have excelled Puck, and put a girdle round the earth in less than forty minutes. At the rubbing of a bit of amber we have summoned a genie to our feet which has surpassed Aladdin's in the works of magic it has accomplished. Men have stepped into an aïrplane in Nova Scotia, and this Magic Carpet has carried them over the ocean wastes to a safe landing in Ireland. Even children are already so familiar with the process of tuning in with the radio set that they will offer to get you Detroit, or Davenport, or Pittsburgh, without realizing in the least what a wonderful achievement the radio is. It was truly significant that the first words transmitted over the electric telegraph between Washington and Baltimore in 1844 were a quotation from the 23d chapter of Numbers,—"What hath God wrought!"

For all these amazing triumphs of science have been but the steady revelation of God's truth, which in His own good time and way has been vouchsafed to us. And as we look hopefully into the future we catch visions of even greater things, such as the liberation of atomic energy, which would give us a source of power entirely independent of coal mines or water power.

Let me repeat that the methods of Science have often been misunderstood, and I regret to say that a case in point is now giving many good people unnecessary anxiety and perplexity. I refer to the matter of the campaign against the evolutionary theory of the origin of man. As in the case of all theories, belief in it must rest on the amount and kind of evidence which the theory presents. Some people believe in it,—some do not. Some are familiar with the evidence in its favor,—some are not. It is significant, however, that those most fitted by education and training to appreciate the value or falsity of the evidence adduced in its favor, are the strongest advocates of the theory. Briefly, the theory is *not* that man is descended from the monkey, but that monkey, man, horse, apple-tree, rosebush, and all other living things are descended, or ascended, from primitive forms of life. In the words of Carruth,

> A firemist and a planet,
> A crystal and a cell,
> A jellyfish and a saurian
> And caves where the cavemen dwell;
> Then a sense of law and beauty,
> And a face turned from the clod;
> Some call it evolution,
> And others call it God.

This theory of development was formulated, as all theories are, to explain and correlate facts of observation, of which there are thousands. But its real test, like that of any other theory, lies in its ability to predict additional facts and the lines of research along which to look for those facts. This second duty of a theory has been most splendidly met by the theory of evolution, and using it as a basis for research work in biological laboratories, medical schools, hospitals, and the various endowed institutes for research, such as the Rockefeller Institute, we have made truly wonderful progress in fighting disease, so that the grim terrors of typhoid and yellow fever, of diphtheria, of malaria, of tetanus, of tuberculosis, and other dreaded diseases, have been to a great extent lifted from our lives. It is quite true that we cannot prove the theory to be true. We would find difficulty in proving *any* theory true beyond the possibility of a doubt. While the *facts* of evolution, on which the theory rests, are well known, the *factors* of evolution are still matters of discussion. But as a basis for research the theory has been marvelously fruitful,

and will doubtless continue to be so, because any ill-advised legislation against the holding or teaching of the theory could not prevent its use as a hypothesis to guide experiment even in the states which adopt such legislation, much less in the freer states where untrammeled scientific investigation has made such wonderful progress, putting us all in its debt.

The real danger of such legislation lies in its boomerang, or flare-back effect, so often before noticed when attempts have been made to throttle scientific work.

When the theory of a round earth was offered to oppose what was called the "Scriptural" theory of a flat earth, the theologians thundered anathemas against those who presumed to "deny the Scriptures" by presuming to teach or believe that the earth is round like a ball; when Copernicus proposed the theory that the earth rotates on its axis and revolves about the sun, he was bitterly denounced by the churchmen, especially by Martin Luther, who called him an "upstart astrologer" and a "fool" for "denying the Scriptures" by saying that the earth moved, whereas, he said, the Scriptures clearly state that the earth standeth fast, and the sun and all the stars revolve about it. Copernicus' book was condemned as false, was placed on the Index Expurgatorius, and all procurable copies were burned.

But every school and college throughout the world now teaches the Copernican theory, and he is held in high esteem as one of the really great liberators of the sons of men from intellectual bondage to old and wornout methods of thought.

Again, when efforts were made by earnest and brave men to stop the terrible persecutions for witchcraft which form such a black chapter in the history of the church, and under which tens of thousands of men, women, and little children were tortured to death with unspeakable cruelty and in unnamable ways for the imaginary crime of witchcraft, many perfectly conscientious people of the day opposed those attempts as showing a lack of faith in the Bible, which they believed not only taught witchcraft, but clearly commanded, "Thou shalt not suffer a witch to live," and even such a great and good man as John Wesley said in 1768 that "the giving up of witchcraft is in effect the giving up of the Bible."

But happily John Wesley was mistaken in this, and we thank God that the false theory of witchcraft has been banished forever from all civilized countries, while the Bible stands more solidly than ever.

I was once sent a pamphlet entitled "Evolution versus the Bible," in which the author showed his dense ignorance of both evolution and the Bible, but made the same old dangerous argument that if we accept evolution we must give up the Bible. I know that many young men are disturbed by this argument, failing at first to see the fallacy in it. Such an argument is a two-edged sword, for suppose the theory should be proved true? Of course those who lead the movement against the theory of evolution have the laudable purpose of saving our youth from the effects of what they regard as a pernicious doctrine, and thereby of increasing their faith in the Bible, but will it have that effect? Unless history fails to repeat itself, it will *not* have that effect, but will serve to throw suspicion on the Bible, until young men find that what the Bible really means is often quite different from what men try to make it mean.

Let us repeat that it is simply a question of evidence. Those who cannot accept the theory of evolution have a perfect right to offer their own theory of the origin of man, and back it by all the evidence which they can muster. They are free to show how their theory can explain all known facts, and how it can predict other facts and relations not yet discovered. The biologists certainly should have the same privilege in regard to their theory, and then the educated public should be allowed to make up its mind as to which theory seems the better one. The very fact that the anti-evolution propagandists wish to call on the law to help in downing their opponents looks uncommonly like a confession of lack of faith in their own theory.

Fortunately the Bible needs no such assistance, for it has always been able to stand not only against the attacks of its enemies, but also against the persistent attempts of some of its friends to misinterpret and misrepresent it.

Let us then not be anxious about the matter, but rather emulate the quiet faith of the venerable Dr. W. W. Keen, for so many years professor of surgery in the Jefferson Medical College, Philadelphia, whose recently published book bears the confident title, "I believe in God and Evolution."

As to the classification of the sciences, let us look at it in this way. We and all things else are physically made up of atoms and molecules, hence Chemistry is one of the fundamental sciences. But

our bodies are veritable physical laboratories, containing levers, lenses, membranes, resonators, valves, pumps, etc., and we need Physics to explain and describe these things.

But our bodies are not mere machines,—they are instinct with that subtle thing called life, and hence Biology must be added to the list of fundamental sciences. In addition to life we possess mind, so Psychology takes its place in the ranks.

Finally man, though an individual, is a unit of larger groups,—families, organizations, cities, states,—and his relationships are studied in the science of Sociology. So these five may be regarded as the fundamental sciences,—Chemistry, Physics, Biology, Psychology, and Sociology. Then we have the abstract sciences, like Logic, Mathematics, and Metaphysics; combination sciences like Physical Chemistry, Biophysics, Astrophysics, Geology, and Anthropology; special sciences like Mineralogy, Meteorology, Spectroscopy, and Ethnology; and applied sciences like Engineering, Radiography, Medicine, and Metallurgy,—dozens of them,—a truly bewildering list, and new ones being developed all the time.

In conclusion, I wish to emphasize again that Science is a systematic search for the truth, the whole truth, and nothing but the truth, insofar as we may hope to find it by scientific methods. And further, I wish to call your attention to the fact that Science has always had its unselfish and devoted heroes, prophets, and martyrs, many of whom suffered even to the death for their beliefs, or like Dr. Walter Reed, gave their lives willingly to obtain knowledge which would save the lives of others.

And this further consideration: the history of both religious and political systems contains innumerable examples of tyranny and oppression in order to bolster up those systems. For example, take the case of Spain in the Netherlands, or Germany in the 15th century, England in the 16th, or France in the 17th. Or take present day Russia. Or the history of the church in the matter of the Inquisition, the burning of Bruno, the persecution of Galileo, the witchcraft persecutions, or the heresy trials which have persisted even to our day. Science is happily free from these things. To quote Dr. Draper,

"As to Science, she has never sought to ally herself to civil power. She has never attempted to throw odium or inflict social ruin on any human being. She has never subjected anyone to mental torment,

physical torture, least of all to death, for the purpose of upholding or promoting her ideas. She presents herself unstained by cruelties or crimes."

To take an example:—the American Association for the Advancement of Science has something like fifteen thousand members. Did anyone ever hear of it, or any of its subsidiary societies, threatening anybody, or torturing anybody, or seeking to imprison anybody, or seeking to drive any minister from his pulpit, or causing anyone to lose his money or position, or trying to enter politics to gain some advantage thereby, or lobbying at Washington to obtain unfair privileges, or of declaring strikes in order to bolster up salaries for the scientists of the country, or in fact of doing the least unworthy or undignified thing? I wonder if we realize that of all groups of men in all history scientists have had the cleanest and most unselfish record of service to the human race?

Science has always borne herself nobly; she comes into court with clean hands; "her ways are ways of pleasantness, and all her paths are peace."

There have been atheists and agnostics among scientists, as there have been among historians, philosophers, statesmen, and even theologians, but Science pursues the even tenor of her way in the deep faith that the search for truth in the spirit of the command, "Prove all things; hold fast that which is good," is the noblest business in life.

May that be the spirit of this place, dedicated to scientific training and research. May you learn here, like Kepler, to think the thoughts of God after Him, and to believe with Mrs. Browning that

> "No lily-muffled hum of a summer bee
> But finds some coupling with the spinning stars;
> No chaffinch but implies the cherubim.
> Earth's crammed with Heaven,
> And every common bush afire with God."

STRAWBERRY LEAF SCORCH*

By Frederick A. Wolf

Plates 9-15

Introduction

There are several diseases which are known to more or less seriously affect the foliage of the cultivated strawberry. The most destructive of these in North Carolina is known as leaf scorch, a name which was first applied by Stone (20, 21 and 22) in his recent investigations of this disease in the Province of Ontario, Canada. During the summer of 1921, leaf scorch was brought to the writer's attention, and because of the serious nature of the disease, a study of it was begun. The present paper, which contains the results of these studies, although in part a confirmation of the investigations of others, contains also additional findings which contribute to a more comprehensive knowledge of the nature of leaf scorch and of the life history and morphology of the causal organism. It is planned to report subsequently other phases of the investigation which will require additional field and laboratory study and which are, therefore, not yet completed.

Distribution of the Disease

Leaf scorch is manifestly quite widely distributed within the United States as indicated by the several collections which have been made of this disease.

According to the Plant Disease Survey (23), it occurs in Louisiana, Delaware, New Jersey, Connecticut, Illinois, Indiana, West Virginia and New York. Plants affected with leaf scorch and which were sent to growers for transplanting in North Carolina show that it occurs also in Maryland, Tennessee, Kentucky and Florida. Specimens have been received through the courtesy of Mr. L. K. Jones from collections

* Grateful acknowledgement is hereby expressed to my colleagues Dr. S. G. Lehman and Mr. I. V. Shunk, to the former for examination of exsiccati in the herbarium of the Missouri Botanical Garden and for bibliographical help in connection with publications in certain European journals and to the latter for the preparation of sections for certain of the anatomical studies. Valuable service was also rendered by the Missouri Botanical Garden, the New York Botanical Garden, and the Brooklyn Botanic Garden through the gift of seeds and plants of various species of *Potentilla* for use in the inoculation experiments and by the Office of Pathological Collections, Bureau of Plant Industry, for the provision of facilities for examining certain type material.

made in the horticultural grounds at the University of Wisconsin. Kelsey (8) has reported its occurrence in Montana. Outside of the United States Stone (22) has reported its occurrence as a serious leaf disease in many fields within the province of Ontario. In Europe as shown by Farlow's Bibliographical Index (7) and by the exsiccati of Krieger, Oudeman, Saccardo, Rabenhorst and Cooke the disease has been found in Germany, France, Italy, Siberia and Portugal.

ECONOMIC IMPORTANCE

Although leaf scorch has been known to occur in the United States for a period of nearly forty years, it seems never to have been regarded as sufficiently serious to warrant an extensive investigation with the view of determining means for its control. It will be impossible to state to what extent it is to be regarded as a serious economic factor in strawberry culture in North Carolina until data has been collected over a period of years. The disease appears to vary widely in severity of attack depending upon weather conditions, when judged by the observations thus far made and by a knowledge of other diseases of similar nature.

The commercial production of strawberries within the State is confined to Columbus, Pender, Duplin, Sampson and Wayne Counties in all of which the disease was very destructive in the season of 1922 but much less so during the present year. Losses ranging from those which were inappreciable to fifty per cent of the crop, with an average of about twenty per cent, were sustained in Columbus County in 1922 according to estimates furnished by about 200 growers. This is regarded as representative of conditions over the entire area devoted to the culture of strawberries within the state. An idea of the enormity of these losses can be gained when it is recalled that 1101 car loads of strawberries were marketed during 1922 and 1660 during 1923 from eastern North Carolina.

APPEARANCE OF LEAF SCORCH

Lesions of leaf scorch appear not only upon the foliage but also upon the petioles, fruit pedicels, and calyces. Although the lesions vary considerably in appearance in the course of their development they possess characteristics which make it easily possible to distinguish them from other strawberry diseases. Young lesions however may be confused with those formed by the leaf spot fungus,

Mycosphaerella fragariae (Tul.) Lindau. In the mature condition, the lesions of the disease under consideration are large, irregular, purplish to reddish blotches which may coalesce and produce a general discoloration of the leaf, whereas those of the common leaf spot are circular, grayish centered spots with dark red borders. These essential differences in appearance have been pointed out by Dudley (4), Clinton (3) and Laibach (11).

The first visible evidence of the presence of leaf scorch on the leaves of the cultivated strawberry may be noted six to eight days after inoculation as minute, purplish discolorations upon the upper leaf surface. These rapidly enlarge and in the course of another week, extend through the leaf. In this stage, as illustrated in Pl. 12, lower fig., the blotches are irregular in outline and range in size from 1 to 5 mm. Affected leaves are commonly curled with margins rolled up. The dark acervuli may be thickly scattered over the upper surface of the spots at this time, or may not be evident until the leaf becomes dry. The lesions gradually enlarge and coalesce with neighboring ones and the whole leaf at length becomes involved. In this stage, the entire leaf surface may be purplish to reddish, but the leaf margins soon afterward become dry, Pl. 12, upper fig. As the disease progresses, the entire leaf assumes a dry, burned appearance.

The lower leaves are the first to become affected and the new leaves in turn become diseased and dry so that by July or August, in the case of severe infections, the entire plant takes on a dry, burned appearance. Such plants may succumb during summer, or when favorable weather for the growth of strawberries returns during September and October they may form a stunted growth of foliage. Such plants are so lacking in vigor that they will not yield profitable returns in the following season.

The lesions on the wild strawberry, *Fragaria virginiana*, are quite different in appearance from those on the cultivated strawberry, Pl. 15, lower fig. Individual spots are smaller, often remaining pinpoint-like and appear as indefinite-margined, reddish areas. Mature lesions become brownish but retain the reddish tint and are paler on the lower leaf surface. Often the spots are so small as to be entirely covered by a single, black, prominently projecting acervulus. In the case of severe infection, the lesions are confluent and are covered with an abundance of prominent acervuli. When the leaves are moist, a whitish mass of conidia oozes from these acervuli.

The lesions on both petioles and peduncles are similar in appearance in that they are either elongated, sunken, reddish areas or streaks. This form of the disease by interfering with the translocation of materials metabolized in the leaves results in the production of berries which are inferior in size and in extreme cases the entire fruit cluster becomes dry, Pl. 13.

The most serious form of leaf scorch is that on the calyx and is known by the growers as the "dead bur" stage, Pl. 13. The first evidence of infection on the calyx lobes is the appearance of irregular brown areas which commonly begin at the tips or margins. They are apparent when first the plants are in flower. These spots enlarge and come to involve the entire calyx which dies prematurely, instead of remaining green until after the berries have been picked. Fruits whose calyces are dry are very inferior in size. They furthermore are less attractive and hence less marketable so that both quantity and quality are seriously affected by the dead bur form of leaf scorch. Acervuli are formed in abundance on the calyx lobes.

MORPHOLOGY AND DEVELOPMENT OF THE CAUSAL ORGANISM

The acervuli most commonly occur on the upper leaf surface, Fig. 6, and rarely occur on the lower, Fig. 7, except when the normal position of the leaf surface has been maintained in a reversed condition. On some lesions they have been found to occur on both leaf surfaces. They are easily visible to the unaided eye, and appear on the central portions of the lesions as black, somewhat arched points. In section, the acervuli may be noted to have formed between the cuticle and the outer wall of the epidermal cells. They vary in diameter from 100 to 200μ. The stroma of the acervulus consists of a thin hyaline to yellowish layer of fungous cells and is seated directly upon the epidermal cells. The conidiophores arise from the upper side of this stromatic layer and appear as short, perpendicular, cylindrical cells. These give rise at their apex to successive crops of conidia. The great numbers of conidia which are formed beneath the cuticle, the only outer covering for the acervulus, exert such a pressure as to cause the cuticle to be ruptured, and an irregular orifice to be formed which exposes the conidia and permits them to escape, Fig. 1.

Preparations made by scraping the lesions with a scalpel and mounting these scrapings show conidia in abundance, often with conidiophores attached. These conidiophores are at most 3 to 10μ long and 3 to 4μ in diameter. The conidia are hyaline, asymmetrically two-celled with the upper cell larger and beaked, curved, constricted at the septa, guttulate and measure 18 to 30 x 5 to 7μ, Fig. 9.

Preliminary observations had indicated that infection must occur through the upper leaf surface from which stomata are absent. It has been possible to confirm this observation and to follow the course of infection and the development of the acervuli by the use of artificially inoculated plants. Since it was found to be impossible to strip off any considerable area of the cuticle of strawberry leaves by breaking and tearing as is usually done, thin free hand sections were cut parallel to the leaf surface. By diligent examination of sections prepared in this manner, it was found that 36 to 48 hours are required for infection to take place. The conidia germinate within 18 to 24 hours, and the infection hypha comes in contact with the host directly over a lateral wall of the underlying epidermal cells, Fig. 2. It penetrates the cuticle at this point but whether this is accomplished by mechanical pressure or by dissolution of the cuticle has been impossible to determine. At any rate, no appressorium is formed and as soon as the cuticle has been penetrated, the hypha commences the formation of a subcuticular mycelium. Within a few days, this mycelium will have formed a subcuticular network, Figs. 1 and 13. Meanwhile, it will have sent out branches which extend downward between the epidermal cells and between the subjacent palisade parenchyma and mesophyll. This internal mycelium by its action on the cell contents develops the characteristic color of the lesions although the mycelium itself remains colorless. Within eight or ten days after inoculation, at certain points on the subcuticular strands a more or less circular structure will begin to be formed which increases in diameter in a centrifugal manner. This is the stromatic layer which within three or four days will have developed into a mature acervulus, Fig. 1.

It was found to be impossible to secure suitable paraffine sections for a detailed study of the relation between fungus and host by appropriately preparing fresh strawberry leaves, because of the fact that the tissues contained such an abundance of calcium oxalate crystals.

When the crystals had disappeared, however, no difficulty was encountered in cutting suitable sections. This phenomenon was observed to have taken place when the leaves were excised and kept in a moist chamber for several days. It was also noted that crystals were not to be found in senile, moribund leaves. The cause of this disappearance of calcium oxalate is not fully known. There is probably, though, a metabolic need for the calcium and it is utilized in some other chemical combination. At least the fact that the crystals disappear in severed leaves precludes the possibility of their translocation and points to the above conclusion. It would require, however, a very thorough-going investigation of changes in hydrion concentration of the tissues, and in their titrable acidity, and of the influence of illumination and of lowered transpiration and respiration in order to determine the entire chain of factors which operate as causes and effects in this disappearance of calcium oxalate crystals. This in itself would be an interesting problem to which the student can be initiated by reference to the early work of Montverde (12).

After sectioning, Durand's (5) method for differentiating the mycelium was employed with success. When also the tissues were stained in toto with alcoholic eosin, the position and extent of the mycelium could be readily determined. The mycelium is intercellular, with haustoria which penetrate the host cells, Fig. 5. The haustoria may be recognized as oval to elliptical bodies surrounded by a sheath of cellulose which is deposited by the protoplasm of the invaded cell in a manner well known in the case of a considerable number of parasitic fungi.

The structure of the acervuli is thus seen to be in accord in all essential features with the findings of Laibach (11), as illustrated in his Fig. 1a, and of Stone (22), as shown in his Fig. 3, in their studies of the leaf scorch fungus. The same conidial stage type furthermore is represented by the black spot disease of roses (25) and by *Marsonia juglandis* (10) on walnut.

When decaying strawberry leaves which had become infected during the previous season are examined in early March, the lower surface of the old lesions is found to be occupied by small black dots, Pl. 14, easibly visible to the unaided eye. These represent the ascigerous stage which in some cases appears on both leaf surfaces, but is always most abundant on the side next to the ground. The

ascocarps were first found to be mature in early March but could be found at any time thereafter throughout a period of about two months.

A study of the development of these ascocarps was made possible by fixing material at different times and by taking advantage of the fact that not all fruit bodies on the same leaf are in the same stage of development at any one time. Sections of this material show that, in an early stage, the ascocarps are represented by an undifferentiated layer of stromatic tissue immediately above the lower epidermal cells. This stroma is several cell layers in thickness and the cells of which it is constituted have thickened brown walls. This stroma becomes lenticular in shape and the cells in the central portion become thin-walled with a more deeply staining content, Fig. 15. This thin-walled tissue is the beginning of the differentiation into the fertile layer, the hymenium. As growth proceeds, club-shaped cells, the young asci, arise from the basal portions of the stroma, Fig. 16, in a palisade-like layer, with the largest near the center and the smallest near the circumference. The hymenium thus enlarges centrifugally. At the same time, the elongation of the asci raises and distends the epidermal cells and the cuticle, Figs. 14 and 19. The upper portion of the fertile stroma persists as a continuous, delicate covering over the hymenium until the ascocarp is nearly mature. It is only by the elongation of the asci and the consequent increase in pressure that the cuticle and hymenial covering are broken and the epidermal cells are turned backward along the margin. This results in a lacerate-margined opening of the apothecia with fragments of the hymenial covering persisting at the margin of the orifice, Fig. 20. Mature apothecia are discoid in shape and vary in diameter from 120-300μ. The excipulum is dark brown to black and the hymenial surface is yellowish to brown. The apothecia can be made to open and close repeatedly as governed by the supply of moisture.

The abruptly capitate paraphyses, which are unbranched, extend beyond the asci, Fig. 18. They are 3-3.5μ in diameter with a head 4-5μ broad. The asci are fasciculate, oblong, taper bluntly at the thickened apex which becomes the pore and are 55-70 x 15-20μ. The ascospores are hyaline, elongated, elliptical, curved, unequally two-celled, blunt pointed, guttulate, and vary from 18-28 x 4-6μ, Fig. 17.

ISOLATION AND INFECTION

The writer's attempts to isolate the leaf scorch fungus show that it is to be regarded as a rather difficult operation, a conclusion which is in accord with the experience of a number of others. Dudley (4) states that "A considerable number of artificial cultures of the spores were made, but they did not germinate readily, and at that time no conidia were formed on the mycelium." Laibach (11) says "I got no germination in water or prune decoction. . . . I obtained germinating spores in strawberry leaf decoction on the second day from the start." No mycelium developed however in his cultures, but only short thick-walled germ tubes as illustrated in his Fig. c and the writer's Fig. 12. Voges (24) on the contrary found that the conidia germinate more readily in water than in plum decoction and gelatin or strawberry decoction. In these media most of the conidia were unchanged after eight days whereas others had swollen sufficiently to destroy their original form. When, however, conidia were sown on gelatin enriched with grated potatoes and pears some of them formed rounded brown hyphae, the elements of which he described as chlamydospore-like. Stone's statement (22) on cultural studies is that "the fungus grows readily (although not profusely, as explained in a letter to the writer) in culture on the ordinary media."

The writer's attempts at germinating conidia in tap water have been uniformly successful in numerous attempts throughout the entire year, although during the summer months only a small percentage can be made to grow. Apparently growth ceases however as soon as the reserve material within the conidium has been utilized. As a rule, the germ tube arises from the back or apex of the sickle-shaped upper cell which is at first markedly swollen. Sometimes both cells germinate at the same time, with one or two germ tubes, Fig. 11. When solid media were sown with conidia or were planted with a piece of diseased leaf tissue, no germination nor growth occurred in several scores of isolation trials made during the months of May, June, July, and August. A tissue planting made early in September, however, gave rise to a colony in a Petri dish culture which formed acervuli with abnormal conidia of type shown in Fig. 8. In these attempts, 2 per cent potato agar and dextrose agar varying

in hydrion concentration over a wide range were employed. During fall and spring no particular difficulty was experienced in securing pure cultures of several strains of the leaf scorch organism both from tissue plantings and conidia. The fungus grows slowly, however, since about a week is required before the colonies become sufficiently large to be readily seen. At first, the mycelium is white, and closely appressed. The aerial portions change to pinkish in the course of three or four weeks. The entire colony which is now 3-5 mm. in diameter, becomes tawny to brown, Pl. 15, upper fig. The colonies are not spreading but tend to form elevated, closely compacted masses. On the surface of such masses, one to a few black acervuli are formed within this 3 to 4 weeks' period. The conidia ooze in whitish drops from the mouths of these acervuli. The mycelium, especially in the older parts, tends to form chlamydospore-like elements, Fig. 3. In tube cultures on bean pods, numerous secondary colonies arise from conidia liberated by the parent colony, and the pods come to be thickly coated with elevated, brown, fungous masses. The conidia in tube culture on dextrose agar, potato agar and bean agar were entirely normal and in every respect like those taken from acervuli upon the leaf lesions, Figs. 4 and 9.

In making isolations from the ascogenous stage, agar plates were inverted above leaves bearing mature ascocarps which had been placed upon moist blotters in the covers of the Petri dishes. Within a few hours, a considerable number of ascospores will be found to have been forcibly ejected and can be found adhering to the surface of the agar, when examination is made with a microscope. Pure cultures could be obtained by this method when care was taken to keep the surface of the agar from coming in contact with the leaf. Germination occurs within 24 hours. There is first a very considerable increase in size which is followed by the formation of one or more lateral germ tubes, Fig. 10. Usually the larger cell germinates first. The formation of the colonies proceeds at the same rate as with colonies from conidia. These colonies are identical in appearance with those arising from conidia. All the strains isolated from ascospores matured acervuli and normal conidia within 21 to 28 days after germination, Fig. 4. This evidence of the relation of the conidial and ascogenous stages confirms the findings of Stone (22) by whom the connection was first established.

ARTIFICIAL INOCULATION

Proof of the infectious nature of the leaf scorch organism was completed by Stone (22) and is in accord with the writer's trials as may be briefly recounted at this point. No difficulty is encountered in demonstrating the parasitism of the leaf scorch organism. When suspensions of conidia or ascospores are sprinkled upon healthy strawberry plants, small discolorations are evident upon the upper leaf surface within six or seven days. These develop within a few more days into characteristic leaf scorch lesions. Conidia from pure cultures originating from conidia and from ascospores have each been employed with similar results in several series of inoculation experiments. When diseased plants are set in contact with healthy ones the infection soon appears upon the healthy plants. When this is done in the greenhouse and care is taken to keep the foliage dry, there is little or no spread of inoculum from diseased to healthy leaves, indicating the necessity of films of moisture on the leaf surface to permit infection.

It does not appear that the strawberry leaf scorch organism has ever been employed in inoculation experiments with species of *Potentilla*, although the conidial stage has been called *Marsonia Potentillae* (Desm.) Fisch. and believed to be identical with an organism originally described as occurring upon certain species of *Potentilla*, including *P. anserina*, *P. reptans*, *P. fragarioides* and *P. latifolia*. In Krieger's Fungi Saxonici No. 1347, it occurs on *P. procumbens* and No. 1348, on *Sanguisorba officinalis* as var. *Sanguisorbae*. Accordingly, seed of 31 species of *Potentilla* were secured, only fifteen of which grew, and were used in this portion of the experimentation. These included *P. anserina*, *P. reptans*, *P. sanguisorbifolia*, *P. Hookeriana*, *P. astrakanica*, *P. dissecta*, *P. andicola*, *P. gelida*, *P. glandulosa*, *P. tormentilla*, *P. megalontodon*, *P. Formosa*, *P. hippeana*, *P. canadensis* and *P. heptaphylla*. Inoculations were effected by sprinkling the plants with a suspension of conidia from pure culture, and then covering the plants with bell jars to conserve humidity. In other trials, the inoculum consisted of diseased strawberry leaves, which were placed upon the wet foliage of the species of *Potentilla*. In the case of *P. anserina*, which has been listed as a host, inoculations were also attempted by setting diseased strawberry plants in such close proximity that the leaves intermingled. No evidence of infection has

been secured by any of these methods of inoculation, although infection of *Fragaria* may be readily secured by any one of them. The conidial stage of the strawberry leaf scorch is not believed, therefore, as will be discussed later, to be identical with *Marsonia Potentillae* (Desm.) Fisch. on *Potentilla*. It is desirable, of course to attempt the reciprocal inoculations but the organism from *Potentilla* has not been available for such experiments.

SUSCEPTIBILITY OF SPECIES AND VARIETIES

It is very evident from inspection of plants in the field that marked differences exist in susceptibility to this disease of different species and varieties when they are grown side by side. One variety may be badly affected whereas another may show little or none of the disease. So far as the growing of strawberries in North Carolina is concerned, only two varieties have commercial value, the Klondike, which is very susceptible, and the Missionary which is moderately susceptible. Other varieties, however which include Excelsior, Lady Thompson, Aroma, Brandywine, and Gandy have been noted within the state. The first of these is very susceptible, the second moderately susceptible, and the others appear to be entirely free from disease.

The plantings at the University of Wisconsin if classified on this basis* show that the varieties, Big Wonder, Charles First, Glen Mary, Peerless, Sample and Superb, are very susceptible; Gibson and Black Beauty, moderately susceptible; Majic Gem, Paul Jones, Stevens, Uncle Jim and Sionilli, slightly susceptible; and Senator Dunlap, Aroma, Brandywine, Kellog's Premier, Progressive, Wolf, Big Late, Bun Special, Doctor Burrill, Joe, Kellog's Prize, Merrick and Warfield, free from disease.

Certain varieties differ in susceptibility to disease in different localities as shown when comparison is made of those just enumerated with those grown in Ontario as listed by Stone (22). The same is true as regards different species since Laibach (11) has pointed out that *Fragaria vesca* and *F. viridis* in Germany are very susceptible, whereas *F. grandiflora*, *F. moschata*, and *F. virginiana* remain free from disease. Peck (15) has recorded the occurrence of the disease on this last named species in New York and in another portion of this report it has been described on this species in North Carolina.

* Data furnished through the courtesy of Mr. L. K. Jones.

LIFE HISTORY OF THE LEAF SCORCH ORGANISM

Strawberries in North Carolina remain green throughout the entire year, but make little growth during that half of the year covered by the three months of summer and the three winter months. During these two periods, the fungus is not destructive, but its periods of greatest activity appear to coincide with those which are favorable for the growth of the host. Lesions bearing mature acervuli and conidia may be found at any time, however, throughout the year. The first infections appear with the advent of warm weather in early spring. These early infections arise, for the most part, from the ascigerous stage or winter stage, which is at that time maturing its crop of ascospores on the decaying leaves of the previous season's growth. These ascospores are violently expelled from the ascomata and by the aid of air currents find lodgment on the newly formed leaves. If moisture conditions are favorable, infection follows and leaf spots are developed. A period of about two weeks only is necessary for the maturation of a crop of conidia on these spots.

Whether or not these conidia will in turn give rise to new infections and they in turn to others, appears to be governed entirely by rainfall and humidity. No data have yet been assembled to prove this point, but the fact that leaf scorch has not been regarded as a serious disease in other parts of the United States may be due to the fact that abundant rainfall, high relative humidity and heavy dews, as occur in eastern North Carolina, are necessary for the development of the disease in epidemic form.

The infection of the calyces of flowers and young berries causes these fruits to fail to mature properly. When the calyces are involved, the fruits are dwarfed and at maturity are lacking in flavor. By the latter part of May or early in June, the close of the picking season, the whole field may have the appearance of having been burned over. This is most pronounced in plantings three or four years old and is not so prominent in new plantings. Plants whose foliage is destroyed at the beginning of summer do not have sufficient vigor to form robust runner plants, but form instead spindling ones which growers call "hard" plants and which cannot be made to yield profitable returns when transplanted.

The conidial stage is not strictly parasitic as is the case with many imperfect fungi which possess a perfect stage also, but an abundance

of new acervuli and conidia are developed in spring among the ascomata on the dead leaves. They are most abundant on the leaves in contact with the soil, especially on those whose lower leaf surface is uppermost. These conidia are viable and no doubt are responsible for a portion of the early infections.

Leaves, moribund or dead, as the result of leaf scorch infection in North Carolina are commonly abundantly occupied by *Septoria aciculosa* E. and E. as determined by comparison with type material from the collections in the herbarium of the Missouri Botanical Garden. This fungus, first collected in Illinois in 1883, may be recognized by the presence of black spots composed of groups of pycnidia. These pycnidia are 90 to 100μ in diameter and occur for the most part on the lower leaf surface. The conidia are slightly curved, faintly septate and 20-30 x 1-1.5μ. This fungus, as determined by inoculation trials with pure cultures, is not parasitic but is active only in the disintegration of dead tissues and takes no part in the enlargement of leaf scorch lesions. This is in accord with the recent observations of Anderson (1) made in connection with his studies of the *Dendrophoma* blight of strawberry in Illinois.

Septoria aciculosa E. and E. was noted to be quite similar to *Rhabdospora fragariae* Atk. (2) as judged by the descriptive account published in 1908 and consequently was compared with the type, No. 21981, in the herbarium of Cornell University. This type specimen was loaned through the courtesy of Dr. H. M. Fitzpatrick, and found to be identical with *Septoria aciculosa*. The two names *Septoria aciculosa* E. & E. (Bull. Torr. Bot. Club **11**: 73, 1884; Sacc. Syll. Fung. **3**: 511, 1884), (18) and *Rhabdospora fragariae* Atk. (Ann. Myc. **6**: 59, 1908) are therefore synonymous and, because of priority, the former name should be retained.

TAXONOMY OF THE CAUSAL ORGANISM

An examination of mycological literature shows that the strawberry leaf scorch fungus has been assigned several different generic and specific names. It will become apparent as the discussion of this portion of the paper proceeds, that several cogent reasons may be given for this state of confusion as to the appropriate binomial. In the first place, the conidial stages of the organisms on *Potentilla* and *Fragaria* have been regarded as identical, a conclusion which is not

tenable in the light of the inoculation experiments previously reported in this paper. This situation is further complicated by the fact that several binomials have been proposed for the conidial stage of the organisms both on *Potentilla* and on *Fragaria*. The fungus on strawberry seems first to have been given the name *Leptothyrium fragariae* by Libert and to have been distributed under this name in her exsiccati (Lib. Crypt. Ard. Cent. II, No. 162, 1832). In 1849 Montagne (13) described *Gloeosporium* as a new genus and stated that in his opinion *Leptothyrium fragariae* Lib. belonged in the genus *Gloeosporium*, in which he placed it with the combination *Gloeosporium fragariae* Mont. This binomial was accepted by Kickx (9) in his cryptogamic flora of Flanders.

In 1887, Saccardo (16) described what appears to be the same organism as *Ascochyta fragariae* Sacc. on leaves of *Fragaria vesca* and *F. chiloensis*. His account is at variance in two important features with those known for the conidia of the leaf scorch fungus, in that he says the conidia measure 12-14 x 2-4μ and are not constricted at the septa. In explanation for these discrepancies, it can only be suggested that the material which he studied must either have been immature or badly desiccated.

In 1884, Peck (15) found on *Fragaria virginiana* a fungus which he described as *Ascochyta colorata*. He pointed out that it differed from *A. fragariae* Sacc. in the color of the spots and in the size and character of the conidia. This difference in character of lesions which Peck noted is in accord with the writer's observations on the appearance of the leaf spots on *Fragaria virginiana* and on cultivated strawberries. Peck's Fig. 10 faithfully represents the type of conidia of the leaf scorch fungus in North Carolina. His measurements, however, which are given as 7-10 x 3-3.5μ are scarcely half as large. The measurements of conidia made by Dudley (4) in his account of the strawberry disease in New York are 14-27 x 4-5.6μ. Although these dimensions are in excess of the forms of Ascochyta on strawberry leaves described both by Saccardo and by Peck, Dudley is of the opinion, in which the writer concurs, that they are all one and the same species.

Subsequently, Saccardo must have found that the conidial fruit bodies are not to be regarded as pycnidia but as acervuli since in 1896 (17) he used the name *Marsonia fragariae* Sacc. but regarded it as synonymous with *Marsonia Potentillae* (Desm.) Fisch., a name

which had earlier been applied to an organism parasitic on several species of *Potentilla*. The close relationship between the genera *Potentilla* and *Fragaria* and the morphological similarity of the two species of *Marsonia* must have convinced Saccardo that the fungi were identical. At any rate, no evidence of the performance of reciprocal inoculation experiments has come to light and acceptance of the identity of *Marsonia Potentillae* (Desm.) Fisch. and *M. Fragariae* Sacc. appears to be based only on Saccardo's statement.

The following names were first applied to the organism on species of *Potentilla*, and in various exsiccati are used also for the one on *Fragaria*, but are not regarded as synonymous with the conidial stage of the strawberry leaf scorch fungus. The history of this synonomy is briefly discussed in Oudeman's (14) paper and in the light of our present knowledge, these names apply only to the *Potentilla* fungus.

Phyllosticta potentillae Desm. Ann. d. Sci. Nat. **8**: 31. 1847.

Leptothyrium dryadearum Desm. Ann. d. Sci. Nat. **9**: 277.

Septoria Potentillarum Fl. Symb. Myc. **1**: 96, pl. 2, fig. 50. 1869.

Gloeosporium potentillae (Desm.) Oud. 26, Jahrg. Ned. III, p. 3. 1872.

Marsonia potentillae (Desm.) Fisch. in Rabenh. Krypt. Flora. Bd. 3. 1872.

The ascogenous stage was first collected by F. S. Earle near Anna, Ill., in May 1883. It was named in his honor, *Peziza earliana*, by Ellis and Everhart (6). In their account, the diameter of the ascomata is given as .12-.17 mm., the asci measure 50-55 x 12μ and the ascospores 15-18 x 2.5-3μ. The fungus was later transferred to another section of the Pezizeae by Saccardo (19) under the name *Mollisia earliana* (E. & E.) Sacc., but very probably through typographical error, the measurements of ascomata are given as 1.2-1.7 mm.

As a result of the investigations of Stone (21 and 23) this ascogenous stage was first connected with the *Marsonia* stage in 1919.

In order to establish the identity of the writer's collections they were compared both with the Ellis and Everhart type in the Office of Pathological Collections, Bureau of Plant Industry, and with specimens from the collections of Dr. Stone, with whom specimens

were exchanged. The North Carolina material is beyond doubt identical with that from Canada and with the type. This opinion is in accord with that expressed in correspondence by Dr. Stone in which he also reports in a letter dated May 14, 1923, the finding of two-celled ascospores in his own collections. The writer had found the two-celled ascospores in the collections from Canada but was unable to find them in the type specimens, which were badly shrunken and which may not have been mature at time of collection as indicated by Ellis and Everhart's measurements.

The genus *Mollisia* possesses ascospores which are hyaline and continuous so that the leaf scorch organism with biloeular spores cannot properly be regarded as a species of *Mollisia*. Moreover the texture of the ascomata of this fungus and the studies of their origin and development do not accord with the Saccardoan concept of members of the *Pezizeae*. The whole aspect of the opened apothecia with their ragged margins of upturned epidermal cells is indicative of the *Phacidieae*, to anyone familiar with this order. Among the didymosporous *Phacidieae*, however, where it beyond doubt belongs, it will be found that there are no organisms which possess morphological characters like the strawberry fungus and which closely resemble it. It is perhaps most like *Fabrea* to which genus some might be inclined to assign it, but until a thorough-going investigation of this genus as well as such related genera as *Phacidium*, *Pseudopeziza* and *Schizothyrium* has been made, it cannot with certainty be placed in any of these genera.

Many striking similarities are presented by the fungus from strawberries when comparison is made with the organism causing black spot of roses, (25), a form with which the writer is familiar because of earlier investigations. Both the rose black spot fungus, *Diplocarpon rosae* Wolf, and the strawberry leaf scorch fungus have acervuli which correspond to the generic type *Marsonia* in all respects except that they are subcuticular. The mycelium of each consists of subcuticular strands, each composed of several anastomosing hyphae which form a subcuticular network. The origin of the acervuli of each on this subcuticular mycelium is similar. The conidia of each are similar in all features. The character of the growth of each in culture so far as form of colonies, their color and their rate of growth are concerned, is entirely similar.

The ascogenous stages of each so far as concerns the origin, development and dehiscence of their ascocarps and the type of asci, paraphyses and ascospores are similar in all respects except one, namely: the subcuticular shield possessed by the rose black spot fungus. In this former paper (25) it was pointed out that the rose black spot fungus possesses many characters indicative of the *Phacidieae*. In spite of this, it was suggested, primarily because of this shield, that the rose disease organism should be placed in the *Microthyriaceae*. When intrepreted in the light of the present investigations with the leaf scorch organism, the presence of this shield need not be regarded as of special significance, for the reason that both acervuli and ascocarps appear on the upper leaf surface in the case of the rose leaf spot organism, whereas the acervuli of strawberry leaf scorch appear on the upper leaf surface and the ascocarps on the lower. The internal mycelium immediately subjacent to the acervulus becomes the locus of the fertile stroma for the rose parasite, and, during the winter period, the stroma for the acervulus becomes transformed into the shield. In the case of the fungus on strawberries, however, the internal mycelium which becomes the fertile stroma is developed immediately above the lower epidermis and thus distant from the old acervuli whose stromata therefore, have no function in the formation of ascocarps.

As has been stated, ascocarps of the parasite of strawberry may appear on the upper leaf surface, a situation which might be anticipated would shed light on the problem of the significance of the subcuticular stromatic layer. These ascocarps too are subepidermal but it has been impossible to find that they are in any way connected with the subcuticular mycelium or with the acervuli of the previous season's growth. This is contrary to the condition which exists with the rose black spot fungus and hence contrary to expectation with the one on strawberry. It would appear from this that one could, with good reason, regard the presence of the shield in the case of the organism which causes the black spot disease of roses as of no especial taxonomic significance. On the other hand, it might equally logically be maintained that the rose disease organism is an intergrading form which possesses characteristics of both the Microthyriaceae and the *Phacidieae*, and thus shows their phylogenetic relationship. This can only be known when the development of the perfect stage of other subcuticular Marsonias has been investigated.

At the present time, it appears most reasonable to modify the generic concept of *Diplocarpon* so as to include the leaf scorch fungus and to transfer this genus from the *Microthyriceae* to the *Phacidieae*. If these emendations be made, the genus might be briefly characterized as follows:

Diplocarpon Emend.

Ascocarps entirely distinct in origin from an extensive subcuticular mycelium and consisting only of an innate erumpent apothecium, or formed in connection with this subcuticular mycelium, and consisting of a subcuticular circular shield with more or less radiating elements especially at the margin, and an innate apothecium. Shield together with the radiating strands on which it is formed, dark brown, without a central pore. Apothecium at first separate from the shield joined only here and there by hyphae which pass between the epidermal cells. Apothecium joined with the margin of the shield at maturity. Hymenium covered by the shield and upper part of the apothecium which at maturity rupture in an irregular, stellate manner. Asci oblong to subclavate, 8 spored; paraphyses capitate, unbranched; spores curved, elongated, unequally two-celled, hyaline at maturity.

Conidial stage of the type with subcuticular acervuli.

Ascomatibus innato erumpentibus, mycelio subcuticulare ex toto discretibus, vel scutellum subcutaneum et apothecium innatum constitutis; scutello mycelio subcuticulare, lato extenso, atro-brunneolo, insidiente; margine radialiter diffuso, contextu membraneo, astomate; apothecio innato, primo scutulo separato, maturitate margine adjuncto. Ascomatibus centro stellatim laciniato-dehiscentibus; asci oblongis vel subclavatis, octosporis; paraphysibus capitatis, simplicibus; sporidiis oblongo-ellipticis, bicellularibus, loculis subaequilongis, maturitate hyalinis.

Acervuli subcuticulares statum condicum consistuent.

With these emendations, the characterization as follows would appropriately describe and orient the strawberry leaf scorch organism:

Diplocarpon earliana (E. & E.) n. n.

Syn. *Leptothyrium fragariae* Lib. Crypt. Ard. Cent II, No. 163, 1832.

Gloeosporium fragariae Mont. Ann. Sci. Nat. **12**: 296. 1849.
Ascochyta fragariae Sacc. Mich. **1**: 169. 1877.
Ascochyta colorata Peck. N. Y. Sta. Museum Rept. **38**: 94. 1884.
Marsonia fragariae Sacc. Malpighia **10**: 276. 1896.
Peziza earliana E. & E. Bull. Torr. Bot. Club **11**: 74. 1884.
Mollisia earliana (E. & E.) Sacc. Syll. Fung. **8**: 328. 1889.

Ascigerous stage—Ascocarps are disc-shaped, hypophyllous, sometimes epiphyllous, membranaceous, dark brown to black .12-.3 mm. in diameter, innate but erumpent at maturity, splitting open with an irregular margin and closing when dry. Hymenium yellow to brown. Asci 55 to 70 x 15-20μ, oblong,-cylindrical, fasciculate, narrowed abruptly at the thickened apical portion, eight-spored. Ascospores elongated-elliptical, curved, hyaline, unequally two-celled, the upper larger, constricted at the septa, guttulate, 18-28 x 4-6μ, Paraphyses capitate and unbranched. The ascigerous stage appears in the spring on decaying, diseased leaves.

Conidial stage—Irregular reddish to purplish spots on the foliage which may involve entire leaves and cause the plants to take on a dry, scorched appearance. Lesions on petioles and peduncles elongated spots or streaks, on calyces brown spots. Acervuli epiphyllous, sometimes hypophyllous, black, formed on a subcuticular mycelial network; conidia asymmetrically two-celled, the upper cell larger and rostrate, constricted, curved, hyaline, 18-30 x 5-7μ. The conidial stage may be found throughout the entire year on living parts.

Status asciger—Apotheceis disciformibus, hypophyllis vel interdum epiphyllis, membranaceis, atro-bruneis vel nigris, 120-300μ in diam; ascomatis innatis, demum margine irregulari-laciniato erumpentibus; disco brunneolo. Ascis fasciculatis, oblongo-cylindraceis, supra obtuse angustatis, 55-70 x 15-20μ, octosporis; paraphysibus apice incrassatis, simplicibus; sporidiis oblongo-ellipticis, inaequaliter bicellularibus, infra medium uniseptatis, curvatis, ad septa constrictis, guttulatis, hyalinis, 18-28 x 4-6μ.

Hab. in foliis dejectis Fragariae sp.

Status conidicus: Maculis rufescentibus vel purpurascentibus, confluentibus, demum foliis desiccatis; acervulis atris, mycelio subcuticulare arachnoide insidientibus, epiphyllis, raro hypophyllis; conidiis infra medium uniseptatis, ad apices rostratis, flexuosis, constrictis, hyalinis, 18-30 x 5-7μ.

Hab. in foliis vivis, petiolis, pedunculis atque calycibus Fragariae sp.

An abundant supply of specimens has been deposited in the herbarium of the Missouri Botanical Garden and of the Office of Pathological Collections, Bureau of Plant Industry.

SUMMARY

A disease of strawberries known as leaf scorch has been under investigation during the past two years.

This disease was first collected in Europe nearly one hundred years ago, and has been known in the United States for nearly forty years. It is now known to occur in New York, Connecticut, New Jersey, Illinois, Indiana, West Virginia, Wisconsin, Montana, Maryland, Louisiana, Tennessee, Kentucky, Florida and North Carolina. It is to be regarded as the most destructive disease of this crop in North Carolina and has been reported as a serious leafspot disease in Canada.

Purplish to reddish lesions, which coalesce so as to involve the entire leaf surface and give to the plants a burned appearance, characterize this disease. Affected plants may be very much weakened or may succumb during summer. The disease appears also on petioles, fruit pedicels and calyx lobes. The impairment of the fruit results largely from infection of the calyx or bur.

The organism which causes leaf scorch has two stages, the conidial stage by which the disease is propagated during summer and the ascigerous stage by which it survives during winter. In North Carolina, strawberry foliage remains green throughout the year and viable conidia may be found at any time. Ascocarps form only on decaying diseased leaves in early spring.

Infection occurs from the upper leaf surface by penetration of the cuticle. Lesions are evident six to eight days after inoculation. The acervuli are subcuticular and of the Marsonia type and are formed on a subcuticular mycelium. The internal mycelium is intercellular with bulb-like haustoria.

Ascocarps occur for the most part on the lower leaf surface and are subepidermal in origin. The mature apothecia are erumpent at maturity, and appear as brown to black discs.

Connection between the conidial and ascogenous stages has been demonstrated by the appearance of the two on the same lesions, by

growth in pure culture and by inoculation experiments. Species of Potentilla are not subject to infection by the organism causing leaf scorch of *Fragaria* sps. Not all species and varieties of *Fragaria* are equally subject to attack.

Leaves which are moribund or dead as the result of leaf scorch infection are commonly invaded by *Septoria aciculosa* E. & E., which has been found to be synonymous with *Rhabdospora fragariae* Atk.

The organism which causes leaf scorch has been given, in both stages, several generic names. The ascogenous stage has hitherto been regarded as one of the *Pezizeae* but is herein shown by a study of its morphology and development to be one of the *Phacidieae*. It resembles in all essential features *Diplocarpon* rosae Wolf. *Diplocarpon* has previously been regarded as a member of the family *Microthyriaceae* but is now placed in the discomycetous order, *Phacidieae*. The leaf scorch fungus is herein given the name *Diplocarpon earliana* (E. & E.) n. n.

RALEIGH, N. C.

EXPLANATION OF PLATES

Figs. 1, 2, 6, 7, 8, 9, 11, and 12 are drawn to the same scale as shown for figs. 1 and 9. Figs. 5, 14, 15, 16, 19 and 20 are drawn according to the scale of Fig. 5; Figs. 3, 4, 10, 13, 17 and 18 are drawn to the scale of Figs. 13 and 17.

Plate 9

Fig. 1. Surface view of an acervulus showing its shield-shaped structure, and and position above the epidermal cells and under the cuticle which is ruptured at dehiscence.

Fig. 2. Germination of conidia and penetration of the cuticle above the lateral wall of adjacent epidermal cells.

Fig. 3. Mycelium of *Diplocarpon earliana* in culture. The elements may become chlamydospore-like.

Fig. 4. Conidia formed in culture from isolations from ascospores.

Fig. 5. Internal mycelium showing several stages in the development of haustoria.

Fig. 6. Vertical section of strawberry leaf lesion bearing an acervulus on the upper leaf surface.

Plate 10

Fig. 7. Vertical section of a leaf lesion and the acervulus on the lower leaf surface.

Fig. 8. Abnormal conidia in plate culture made by planting a fragment of leaf tissue.

Fig. 9. The *Marsonia* type of conidia taken from a lesion showing variation in the form and the conidiophores.

Fig. 10. Stages in the germination of ascospores. When compared with mature ascospores, Fig. 17, one can note the very considerable increase in size.

Fig. 11. Various stages and types of germination of conidia.

Fig. 12. Growth of this type is not uncommon for conidia sown on solid media. No growth beyond the formation of chlamydospore-like elements occurs.

Fig. 13. Tip of a subcuticular strand showing the underlying epidermal cells.

Fig. 14. An immature ascocarp, in vertical section, formed on the upper leaf surface showing its origin distinct from the stroma of an old acervulus.

Plate 11

Fig. 15. An early stage, in section, in the formation of an innate apothecium showing the beginning of the differentiation of the fertile stroma.

Fig. 16. A later stage in which asci have begun to be developed.

Fig. 17. Mature ascospores.

Fig. 18. Mature ascus and paraphyses.

Fig. 19. The ascocarp has begun to open as the asci approach maturity as shown in vertical section.

Fig. 20. Section through a mature opened apothecium of *Diplocarpon earliana*. Some of the asci are not yet mature.

LITERATURE CITED

1. ANDERSON, H. W. *Dendrophoma* leaf blight of strawberry. Ill. Agr. Exp. Sta. Bull. 229: 127, figs. 3. 1920.

2. ATKINSON, G. F. Notes on some new species of fungi from the United States. Ann. Myc. 6: 54. 1908. (See p. 59).

3. CLINTON, G. P. Notes on parasitic fungi. Conn. Agr. Exp. Sta. Rept. 27: 360. 1904.

4. DUDLEY, W. R. The strawberry leaf blight. N. Y. (Cornell) Agr. Exp Sta. Bull. 14: 171, figs. 10. 1889. I. On the Strawberry leaf blight. II. On another disease of the strawberry.

5. DURAND, E. J. The differential staining of intercellular mycelium. Phyto path. 1: 120. 1911.

6. ELLIS, J. B. and EVERHART, B. M. North American Fungi. Bull. Torr. Bot. Club 9: 74. 1884.

7. FARLOW, WILLIAM G. Bibliographical Index of North American Fungi. 1, pt. 1: 268. 1905.

8. KELSEY, F. D. Notes on the fungi of Helena, Montana. Journ. Myc. 5: 80. 1889.

PLATE 9

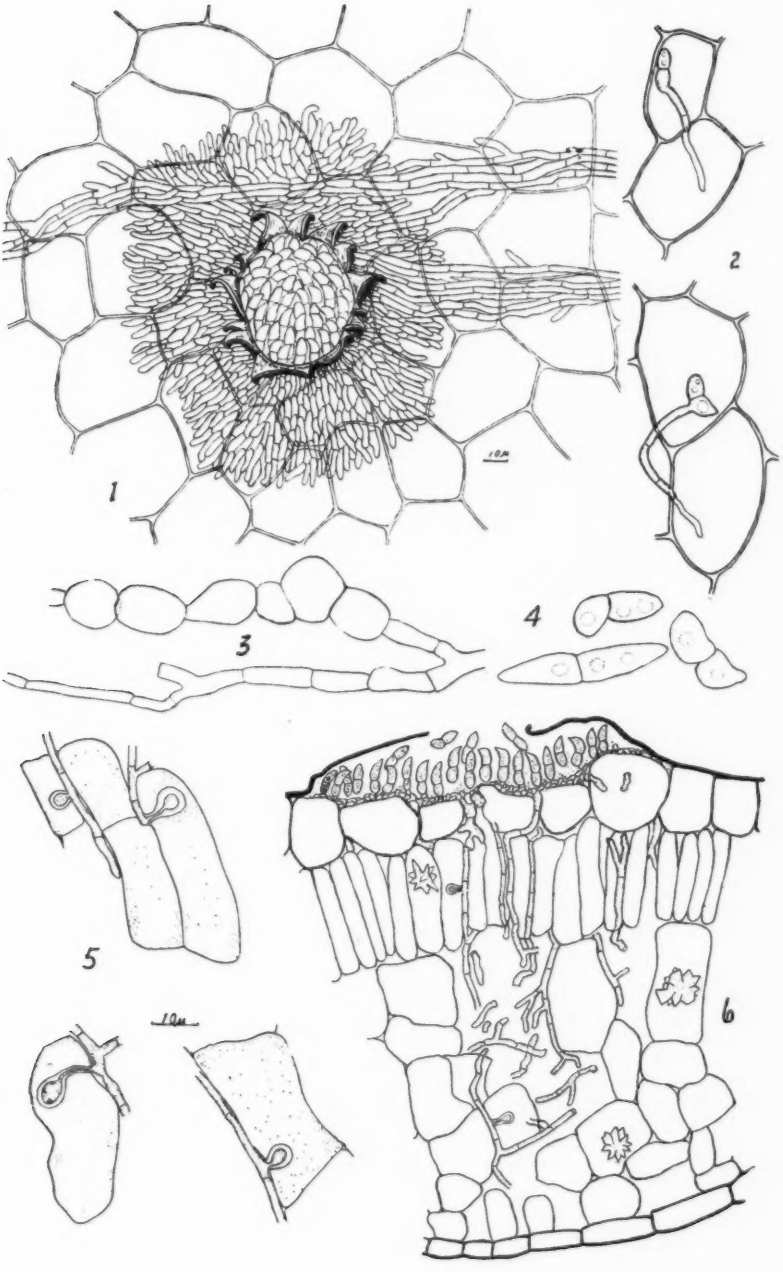


PLATE 10

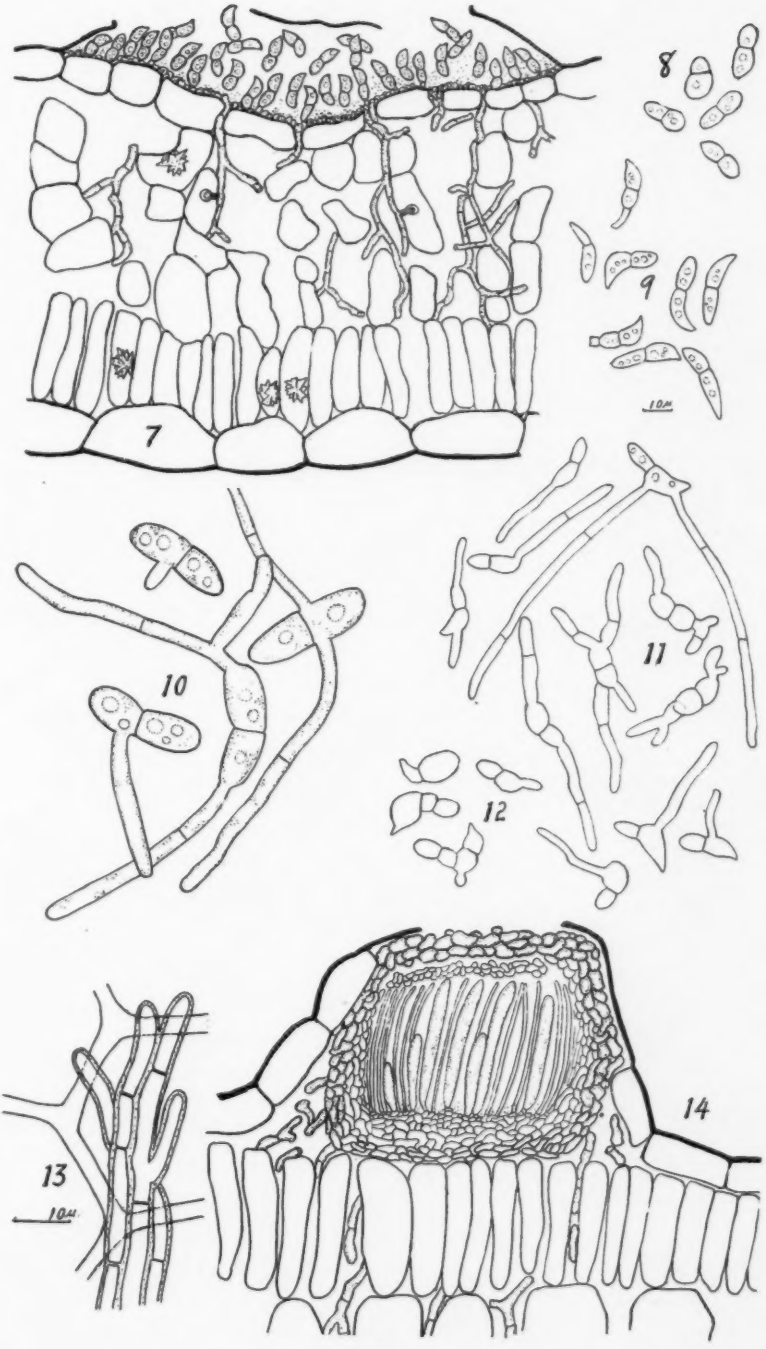


PLATE 11

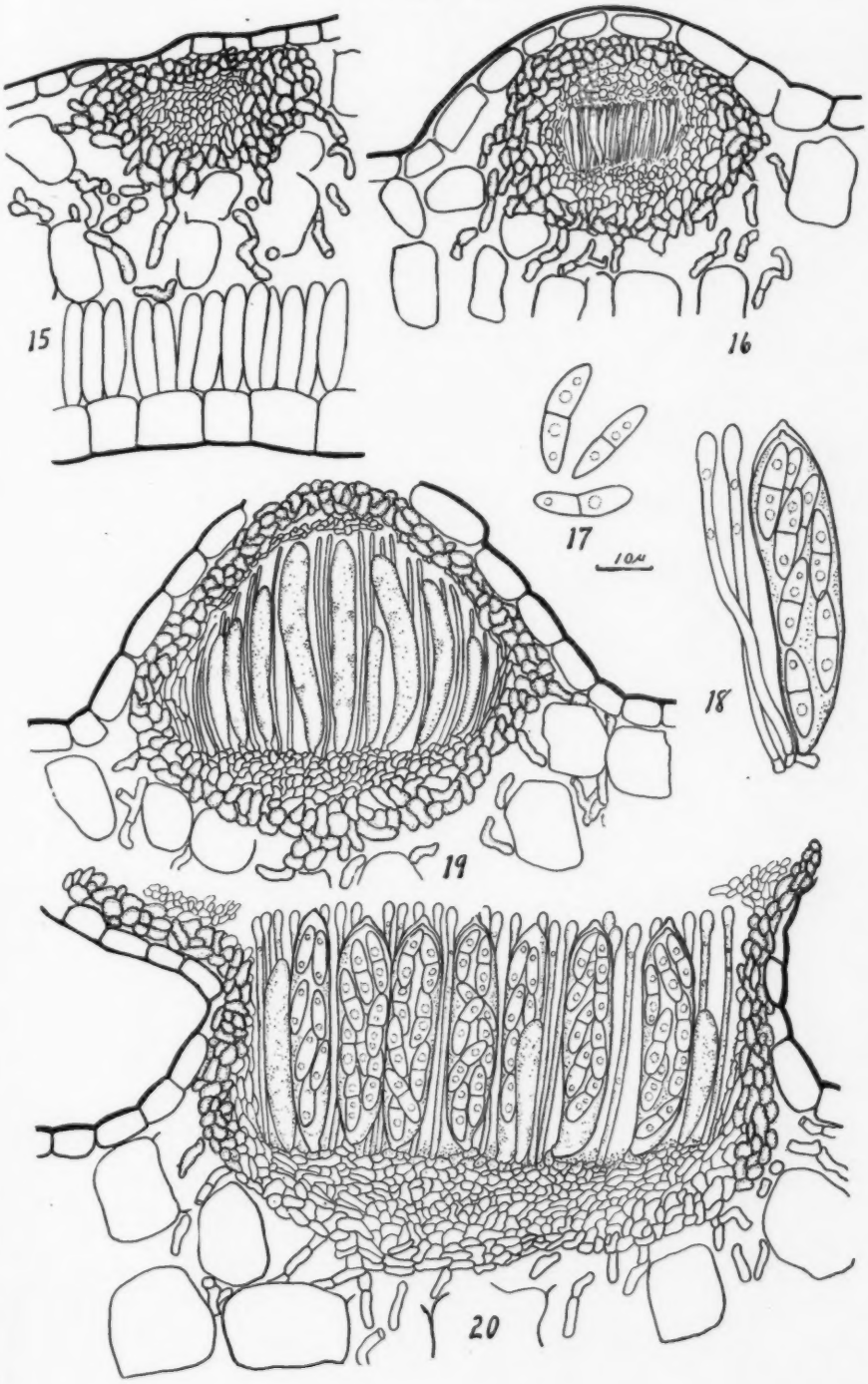
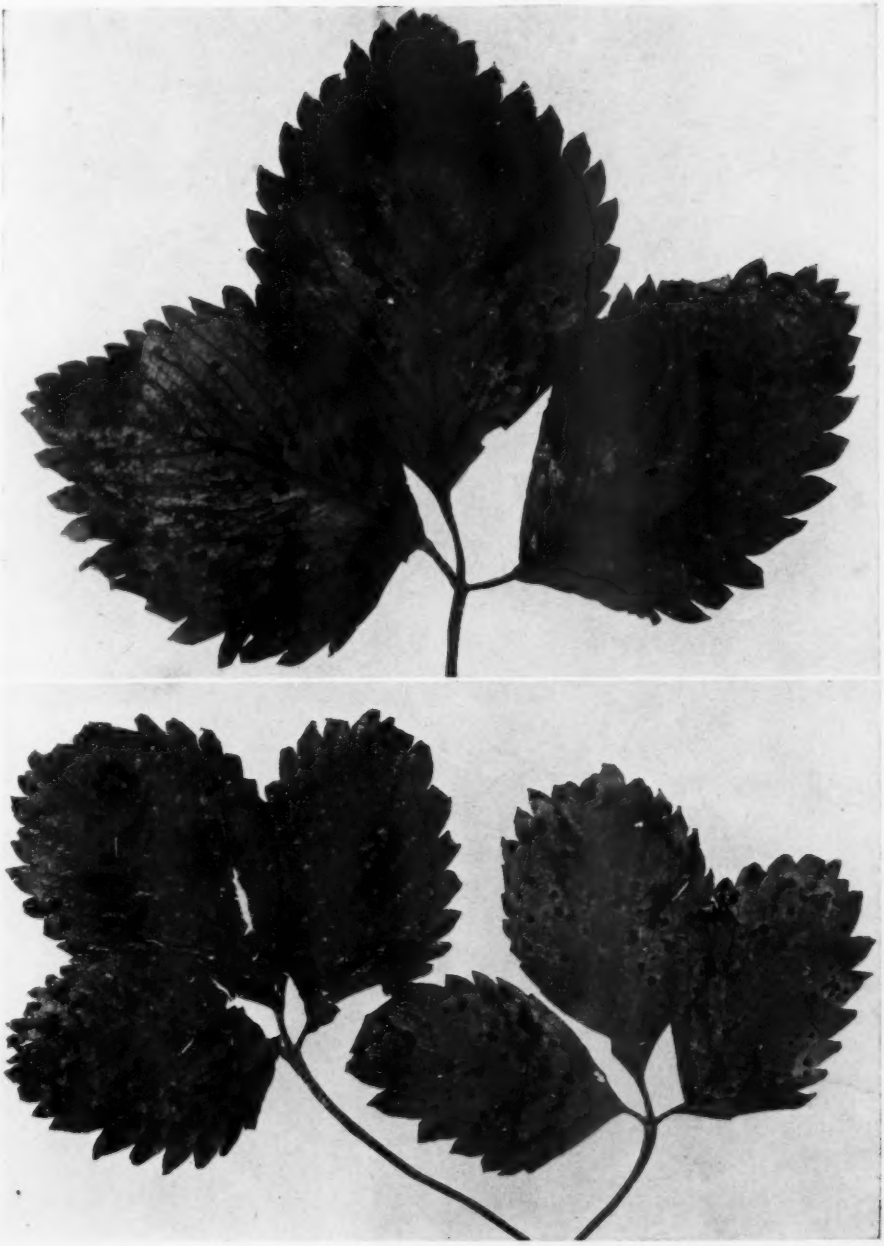


PLATE 12



[Upper fig.] The leaves have begun to dry along the margins.

[Lower fig.] The leaf spot stage of strawberry leaf scorch

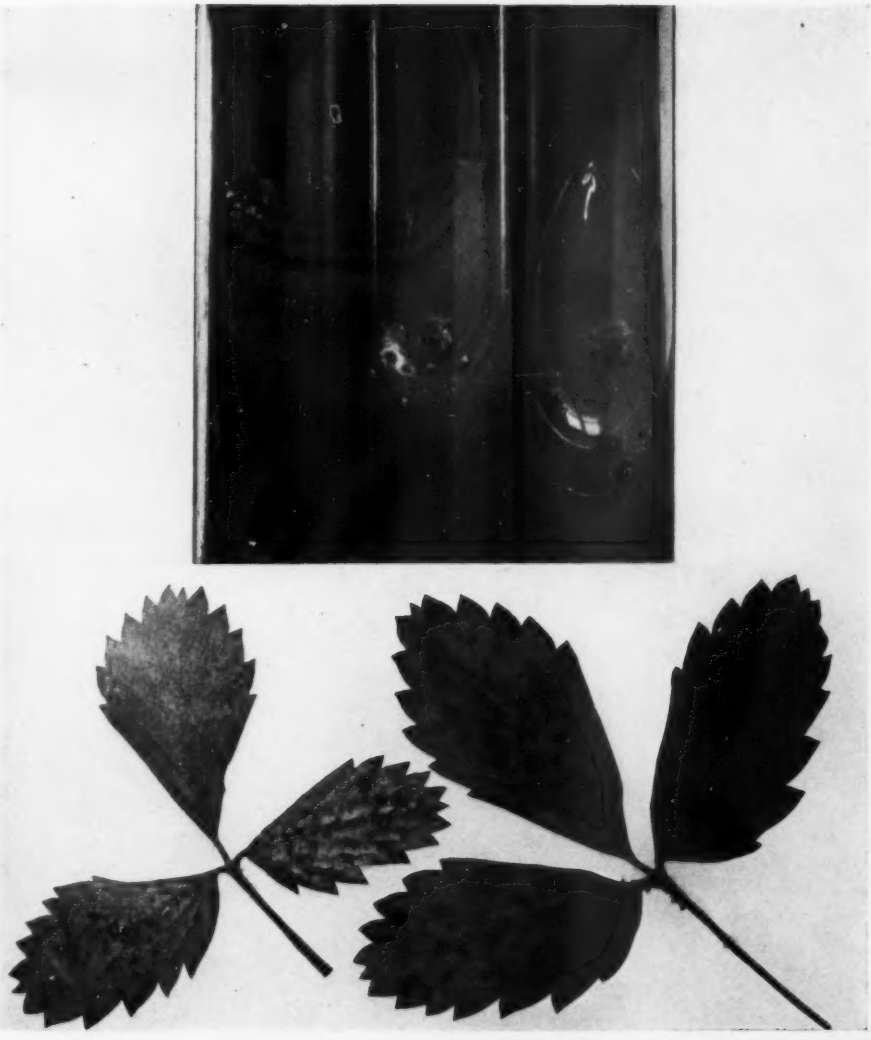
PLATE 13

At the left a fruit pedicel bearing a cluster of dead fruits and above it affected calyces,—the "dead bur" stage. At the right a normal fruit cluster with normal calyx lobes.

PLATE 14

The dark specks, ascomata, on the lower surface of a decaying leaflet.

PLATE 15



[Upper fig.] Artificial cultures of the strawberry leaf scorch fungus, bearing acervuli: (left) on bean pod; (middle) on bean agar, isolated from ascospore; (right) isolation on bean agar, from conidium.

[Lower fig.] Leaf scorch lesions on *Fragaria virginiana*.

9. KICKX, JEAN. Flore cryptogamique des Flanders. Ouvre Posthume. Publee par Jean-Jacques Kickx Vol. 2: 93. 1867.

10. KLEBAHN, H. Untersuchungen ueber einige Fungi imperfecti und die zugehörigen Ascomycetenformen. Zeitschr. f. Pflanzenk, 17: 223, pl. VIII. 1907.

11. LAIBACH, F. Einige bemerkenswerte Erdbeerpilze. Arb. a. d. Biologischen Anst. f. Land- und Forstwirtschaft. Dahlem. Bd. 6, Heft 1: 76, 3 Textab. 1908.

12. MONTEVERDE, N. A. Ueber die Ablagerung von Calcium und Mágnesium Oxalate in der Pflanze. 9 pp. 81, 1 pl. (St. Petersburg) 1889, (Russian) Abstracted in Bot. Centrb. 43: 327. 1890.

13. MONTAGNE, J. F. CAM. Ann. d. Sci. Nat. t. 12: 296. 1849.

14. OUDEMANS, C. A. J. A. Aanwinsten voor de Flora Mycologica van Nederland. 3e Bijlage tot de 26e Jaarvergadering der Nederlandische Botanische Vereeniging. p. 252, figs. 18a and 18b of pl. 10. 1872.

15. PECK, CHAS. H. Rept. New York State Museum 38: 94, pl. 2, figs. 9 and 10. 1884.

16. SACCARDO, P. A. Michelia. Commentarium mycologicae Italicae 1: 169. 1877.

17. SACCARDO, P. A. Mycetes Sibirici, Pugillus Tertius Malpighia 10: 276. 1896.

18. SACCARDO, P. A. Sylloge Fungorum. 3: 511. 1884.

19. SACCARDO, P. A. Sylloge Fungorum. 8: 328. 1889.

20. STONE, R. E. Leaf scorch or mollisiose of the strawberry (Abst) Phytopath. 11: 44, 202. 1921.

21. STONE, R. E. The strawberry troubles of 1921. Canadian Horticulturist (Fruit Edition) 44: 117. 1921.

22. STONE, R. E. Leaf scorch or mollisiose of the strawberry. Phytopath 12: 375, figs. 3. 1922.

23. United States Dept. Agr. Bur. Plant Ind., Plant Disease Bull. Suppl. 14: 97. 1921.

24. VOGES, ERNST. Pathologische Pilzbildungen. Zeitschr. f. Pflanzenk. 11: 207, textab. 5. 1911.

25. WOLF, FREDERICK A. The perfect stage of *Actinonema rosae*. Bot. Gaz. 54: 218, pl. 13. 1912.

A NEW DOWNY MILDEW ON SOYBEANS

By S. G. Lehman and Frederick A. Wolf

Plates 16 and 17

Introduction*

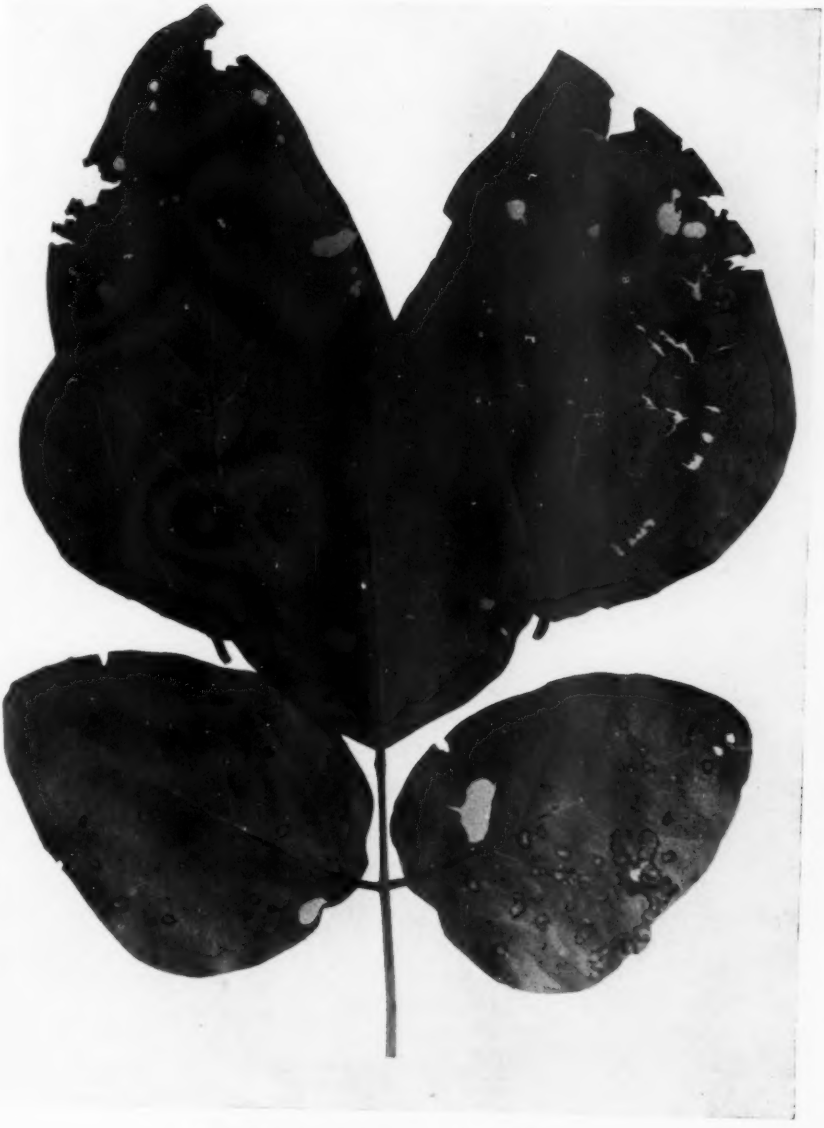
Certain collections of pathogenic fungi on soybean, *Soja max* (L.) Piper, which have been made during the past summer contain a leaf-spot disease caused by an apparently hitherto unreported species of downy mildew. Specimens of this fungus were first taken on August 29 in the vicinity of Raleigh, N. C. On the following day, a correspondent from near Wilmington, N. C., sent for identification specimens of the same organism, and subsequently it has been collected near Tarboro and Willard, N. C. As judged from these four collections made at rather widely separated points, this organism is probably quite widely prevalent in the eastern part of the state. Because of the fact that mention has not been made in previously published accounts of a downy mildew disease of soybeans, this organism has been compared with those on other leguminous hosts. The present report, therefore, contains the results of this comparative study, together with a description of the disease and of the causal organism.

Appearance of the Disease

Downy mildew of soybean appears to be confined to the foliage since no evidence of the disease has been noted on other plant parts. The feature of the disease which first attracts the attention of the casual observer is the appearance of chlorotic areas from 2 to 5 mm. in diameter. These areas have an irregular indefinite margin and on closer inspection many of them will be found to be covered on the lower leaf surface with a grayish conidiophore layer. At this stage

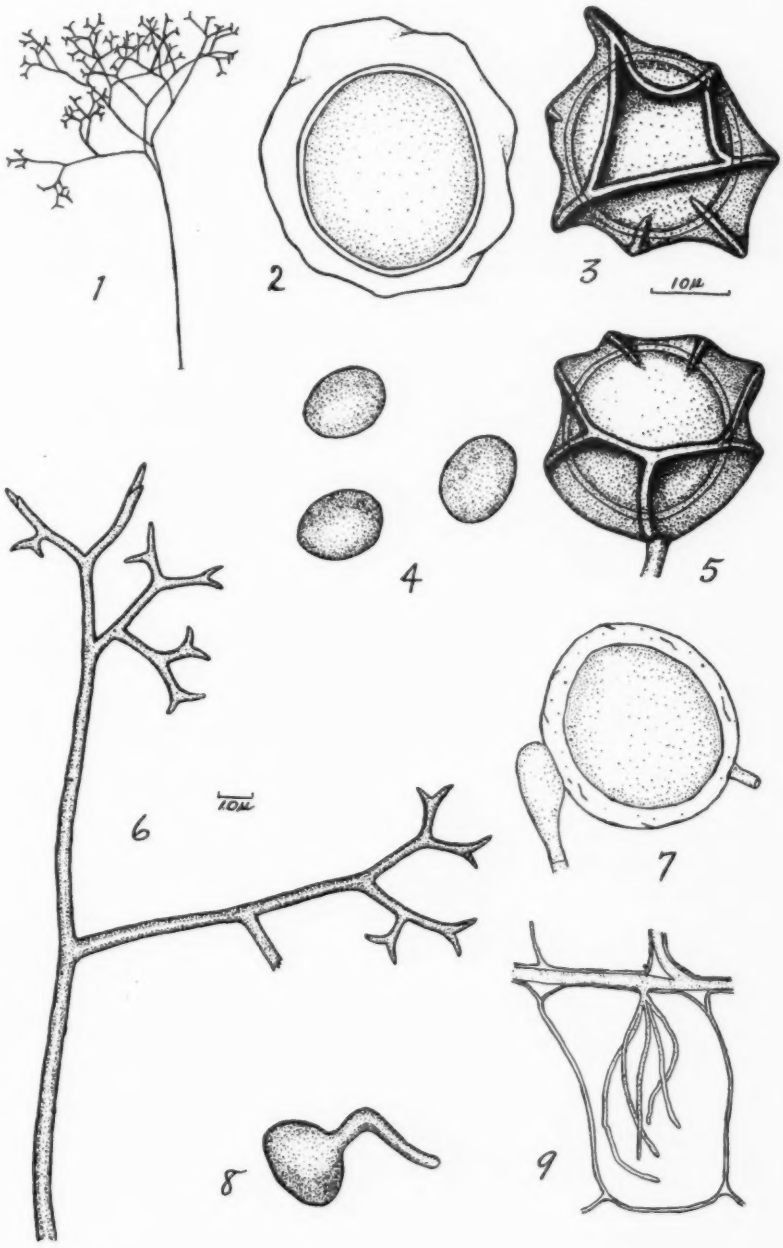
* Since this manuscript was submitted for publication, Mr. M. Miura has sent to the writers a Japanese publication entitled "Diseases of the Main Agricultural Crops in Manchuria" (Agricultural Experiment Station of the South Manchuria Railroad Co., Bul. 11, Jan. 1921). As judged from a translation rendered through the kindness of S. Yonemasu, a Japanese student of textile manufacture, this bulletin contains a brief account of a mildew on soybeans in Manchuria identified by Miura as *Peronospora trifoliorum* De Bary var. *Manchurica* Naoumoff. The writers have not seen the original description of this variety of mildew. The brief description of the disease and of the organism contained in the above mentioned bulletin lead to the opinion that the soybean mildew observed by Miura is possibly identical with the one described in the present account. The question of identity cannot be decided, however, without access both to the original description and to Naoumoff's type.

PLATE 16



Downy mildew lesions on soybean foliage.

PLATE 17



a few to many pin-point-like brown specks appear within each of the diseased areas. These appear to mark the several loci of infection which together develop into a single lesion. As the disease progresses, these brown areas enlarge, fuse, become irregular in outline and may attain a diameter of 5-10 mm., (pl. 16). The two surfaces of the individual lesions commonly present additional differences in appearance as the spots approach the more mature condition. On the upper surface, the spots become gray to grayish brown and are surrounded by a conspicuous dark brown border, ¼ to ½ mm. in width. This narrow brown border is often set off from the normal green of the leaf by a narrow irregular band of chlorotic tissue. On the lower leaf surface, the diseased tissues remain light brown in color with a dark brown bordering zone. These light brown areas are covered over with numerous profusely branched conidiophores which give to the lower surface of the spots a grayish, woolly aspect. These diseased areas may become irregularly cracked and a portion or even all of the diseased spot may fall away giving a tattered appearance to the leaf. The lesions are commonly more numerous on the lower leaves and the disease is usually more abundant in low situations which, because of the adequate supply of moisture, are favorable for rank growth. However, the disease is not confined to such situations since it has been found also at higher elevations although less abundantly. The observations of the past season indicate that downy mildew of soybeans is not to be regarded as the cause of a disease of major economic importance.

MORPHOLOGY OF THE FUNGUS

The mycelium of the downy mildew fungus is intercellular and very small in caliber. The slender hyphae pass between the cells of the host tissue and send long tenuous haustoria into the cells, (fig. 9). The chloroplasts of invaded cells disappear and eventually the entire protoplast becomes disorganized. Conidiophores appear on the lower leaf surface only, emerging through stomata in groups of one to several, and may be so numerous as to form a gray coating over the diseased areas. They have a length of 300-500μ and are 5 to 8 times dichotomously branched, appearing tree-like in general aspect (fig. 1). The ultimate branchlets are pointed, recurved, unequal, and form right to obtuse angles (fig. 6).

The conidia are hyaline, ovoid to subglobose, 24 by 20.5μ and fugaceous, (fig. 4). They germinate in water, at room temperature in September, by the formation of a slender hyaline lateral germtube (fig. 8). Conidia from leaves left in the laboratory for a day or two appear to have lost their power of germination. Conidia have never been found in great numbers at any one time. They are formed apparently within a short interval of time and soon drop from the conidiophore thus escaping observation.

Oospores are fairly numerous in diseased tissues. They are light brown, globose, 18-23μ, and possess a smooth wall about 1μ thick (figs. 3 & 5). Their presence within the tissues may be demonstrated either by macerating diseased tissues or by use of microtome sections cut 15 to 20μ thick. Their relative abundance is indicated by the fact that three or four may occur in a single section of this thickness. Oogonia in different stages of maturity may be observed in any one section. The presence of antheridia accompanying the oogonia (fig. 7) has been difficult to demonstrate, presumably because the collections were not made sufficiently early in the season. Apparently, however, before fertilization is effected, the oogonium has become differentiated into a broad periplasmic layer which surrounds the oosphere, as is known to occur in other downy mildews (fig. 2). The old oogonial wall may collapse after the oospores have become mature and persist for a considerable time as a layer 6 to 7μ thick (fig. 3, 5).

TAXONOMY

The type of the conidiophores and the manner of germination of the conidia of the soybean downy mildew, as recounted in the previous paragraph, are characteristic of the genus *Peronospora.* Three species of this genus have hitherto been described in mycological literature as occurring on leguminous hosts. These include *P. Viciae,* (Berk), De Bary[1], *P. Trifoliorum* De Bary[2] and *P. Ononidis* Wilson[3]. In order to establish the identity of the soybean downy mildew, it has been compared with the diagnostic discription of each of the above named species and with specimens of both *P. Viviae* and *P. Trifoliorum* from Bartholemew's "Fungi Columbiani." This comparison is set forth in tabular form below.

[1] Saccardo, P. A. Sylloge Fungorum, 7:245. 1888.
[2] Saccardo, P. A. Sylloge Fungorum, 7:253. 1888.
[3] Wilson, G. W. A new European species of *Peronospora.* Ann. Myc. 8:185. 1910.

COMPARISON OF PERONOSOPORA ON SOYBEAN WITH OTHER PERONOSPORAS ON LEGUMINOUS HOSTS

ORGANISM	CONIDIA		OOSPORES	
	SIZE	COLOR	SIZE	SURFACE MARKINGS
P. Viciae.....	16-20 x 24-26	light violet	25-30	Few, broad large reticulations
P. Trifoliorum..	15-19 x 19-26	dilute violet	25-34	Smooth
P. Ononidis....	15-20 x 21-25	pale violet	32-33	Covered with minute tubercles
Peronospora from soybean.	20-21 x 24-26	grayish	18-23	Smooth

It will be noted that this tabulation presents little difference in conidial characters between any of the several forms. When comparison is made, however, of the oospore characters, it is apparent that *P. Viciae* with reticulate surface markings and *P. Ononidis* with numerous minute tubercles are quite different from the soybean *Peronospora* and *P. Trifoliorum*, each of which possesses a smooth epispore and falls within the *Leiothecac-Effusae* group. Although the last named forms are similar in these respects, they may be noted to differ considerably in size of oospores. The oospores of *P. Trifoliorum* have a diameter of 25-34μ while those of the *Peronospora* on soybean measure only 18-23μ. Confirmation of the size of oospores of *P. Trifoliorum* was made by examination of material from Medicago sativa from Bartholemew's "Fungi Columbiani." They were found to measure 29-34μ, which accords satisfactorily with the measurements taken from Saccardo as given above. In addition it was found that their wall is 3-4μ thick and the oogonial diameter is 43-47μ. Corresponding measurements of the soybean *Peronospora*, as recounted previously, are 1μ for the thickness of the oospore wall and 29-33μ for the oogonial diameter.

Since the oospores of *P. Trifoliorum* and the soybean *Peronospora* differ so much in size, further attention was given to a comparison of the conidia. The conidia from Bartholemew's specimen on *Medicago sativa* were found to vary from 28 to 31μ in length, and 17 to 20μ in width, with 30 x 18μ as the most common size. The most common conidial size of the soybean mildew was 24 x 20μ, so that it is more nearly globose in form than *P. Trifoliorum*.

These differences in size of the oogonia and of the oospores and in the thickness of their walls together with the differences in size relations of the conidia are therefore regarded as sufficiently great to establish the specific rank of the soybean mildew as distinct from *P. Trifoliorum*. The name *Peronospora sojae* is therefore proposed as the appropriate binomial.

Peronospora sojae n. sp.

Maculis primo luteo-chlorinis, indeterminatis, dein irregulariter angularis, brunneis, 1-10μ diam., pagina foliorum superior brunnea, dein griseola-brunnea, margine fusco-brunnea, atque pagina foliorum inferior brunneola. Conidiophoris caespitulis, hypophyllis, e stomatibus exeuntibus, griseolis, densis totas maculas occupantibus, 300-500μ altis, 5-8μ crassis, circa 5-8-dichotomice ramosis; ramulis ultimis acutis, inaequalibus, recurvatis, angulo recto v. obtuso divergentibus; conidiis ovoideis vel subglobosis, 24 x 20μ, dilute griseis; oosporis globosis, 20-23μ, episporo pallide brunneo, tenue, leve.

Hab. in foliis vivis Sojae macis.

Spots at first chlorotic, indefinite in outline, becoming irregularly angular, 1-10μ in diameter. Necrotic tissues brown at first, upper surface becoming grayish-brown at maturity with a dark brown margin; lower surface of lesions light brown, covered with a copious growth of conidiophores. Conidiophores hypophyllous, caespitose, coming out of the stomates, 300-500 x 5-8μ, dichotomously branched 5-8 times; terminal branchlets acute, recurved, unequal, forming right or obtuse angles; conidia ovoid to subglobose, 24 x 20μ, dilutely grayish; oospores globose, 20-23μ, light brown, wall thin and smooth.

Parasitic on the foliage of *Soja max* (L.) Piper.

Specimens have been deposited in the collections at the University of North Carolina, Chapel Hill, N. C., and in the Office of Pathological Collections, Bureau of Plant Industry, Washington, D. C. ,

SUMMARY

A leafspot disease of soybean caused by one of the downy mildews has been observed in several localities within the state. The disease may be recognized by the presence of indefinite chlorotic areas which change to grayish brown irregular lesions with well defined dark brown borders. A dense grayish coating of conidiophores may

cover the lower surface of the lesions. The casual organism is a species of *Peronospora*, which when compared morphologically with previously described species on legumes is manifestly distinct. It is accordingly described herein as a new species and is given the name *Peronospora sojae*.

RALEIGH, N. C.

EXPLANATION OF PLATE 17

Fig. 1. Diagrammatic representation of a single conidiophore of *Peronospora sojae* showing extent and type of branching.

Fig. 2. Oogonium with differentiating oosphere surrounded by a broad periplasmic zone.

Fig. 3 and 5. Mature oospores surrounded by the collapsed oogonial wall.

Fig. 4. Conidia.

Fig. 6. Conidiophore showing type of branching and character of ultimate branchlets.

Fig. 7. Oogonium in contact with an antheridium.

Fig. 8. Conidium germinating in water.

Fig. 9. Haustoria and intercellular hyphae.

Figures 4, 6, and 8 were drawn to the scale adjacent to fig. 6 and 2, 3, 5, 7, and 9, to the one near fig. 3.

THE GEASTERS OF THE UNITED STATES AND CANADA

By W. C. Coker

Plates 18-36

Plants at first subglobose and with or without an apical beak; either just buried in the soil, trash, or moss they grow in and with or without a fine flocculence all over which binds the substratum to the surface, or in some species seated on the surface of rotting wood, trash, or earth and attached only at the base (epigeal). Outer peridium at maturity splitting from the apex into few or many rays which expand more or less in a stellate way, or even recurve strongly and are composed typically of three layers, the surface one a delicate, interwoven coat of flocculence or tomentum that in some species is scarcely obvious, but in others forms a more or less perfect membrane which remains attached to the next layer on expansion, or becomes more or less detached from it, and in some cases is completely stripped off and remains as an empty sac in the ground when the rest of the plant is lifted out by the recurving lobes of the next layer. This next inner layer, called the fibrous layer, is thicker and tougher and is formed of closely woven, homogeneous fibers. Lining this layer and splitting with it is a third layer of turgid, fleshy tissue which dries out and shrinks after opening, either remaining attached to the inner side of the fibrous layer as a continuous or much cracked cartilaginous-looking membrane or peeling off and disappearing in places or throughout. Sometimes a part is separated and remains as a kind of collar around the center. Inner peridium (spore sac) thin, tough, membranous, pliable, stalked or sessile, opening by a single, apical mouth that is simply a small torn hole or an elevated pore which may or may not be surrounded by a circular area (peristome) of different texture, and more or less sharply circumscribed outline. In one group of species this area is prettily and regularly fluted (sulcate). Gleba composed of small chambers lined with basidia which are 4-8-spored. Spores spherical or subspherical, usually warted or asperulate. Capillitium abundant, composed of simple, rarely-branched threads which arise from the walls and also from a more or less prominent (in some species vague or absent) basal column, the columella.

An interesting genus of numerous species that are popularly known as "earth stars." The dry spores puff out of the mouths as in puff balls, leaving the persistent capillitium behind. The peculiar genus *Myriostoma* is closely related to *Geaster,* but differs in having a number of mouths and several pedicels and in the free capillitium. It has a wide but erratic distribution in this country and Europe, but apparently has not been found in the Carolinas. It is reported from Florida, Dakota, Colorado. Another peculiar plant should be mentioned here, although not found in America. It is *Trichaster melanocephalus* from Europe. It is like a large *Geaster fornicatus* in general appearance except that the inner peridium wall very soon disappears. It differs also in the very large, globose, hard columella around which the capillitium forms a matted mass filled with spores. There is a specimen in Washington under the name of *G. fornicatus* (Myc. and Path. Herb.; Petrak, Fl. Bohemiae et Moraviae exs., No. 1498). It is just like Lloyd's figures (Myc. Notes, p. 189, pl. 17) and has all the characters of the species. The spores are about like those of *fornicatus,* distinctly warted, 3.8-4.5μ. The plant is said to be quite epigean, and this is borne out by the plant just mentioned, as the outer layer has not been stripped off and is furthermore free of trash.

In attempting to find a natural classification for the species of *Geaster,* one meets with difficulties and with differences of opinion among authors. What are the characters expressing the most fundamental relationships; and those of lesser degrees of importance? All arrangements heretofore proposed have in certain sections obviously violated, it seems to us, the true relationships. De Toni (Rev. Mycol. 9: 64. 1887. See also Sacc. Syll. 7[1]: 70, and Hollos, l.c., p. 51) divides the true Geasters first into a fornicate and a cupulate group (Fornicati and Cupulati) and the remaining species which are subdivided into the sulcate-striate group (Striati) and the fimbriate group (Fimbriati). As a result of the first two groupings there are thrown together the very dissimilar *fornicatus* and *radicans,* while the near relatives *fornicatus* and *rufescens,* and *coronatus* and *minimus* are separated. The third group is a natural one, but the last should be rearranged.

Morgan's two main groups, Depelliti and Pelliculosi, are in part natural, but are unnatural in having species with sulcate-plicate peristomes in each. His two sub-groups under Depelliti are unnatural for the same reason. He does not make the mistake of making the

hygroscopic character a leading one. In Lloyd's last outline of the Geasters (Myc. Notes, p. 317), as well as in The Geastrae, he first divides them into the Rigidae and the Non-rigidae, the latter with six groups. This throws together such distantly related plants as *mammosus* and *Drummondii* and separates species with sulcate peristomes.

Of the six groups of Lloyd's Non-rigidae, the first and last are natural in their inclusions, though *Hariotii* is excluded from the first. The other three groups are in our opinion unnatural to a greater or less degree. That the hygroscopic character is not the most fundamental one seems obvious. Both hygroscopic and non-hygroscopic species are found in the very natural group with sulcate peristomes, as well as in the non-sulcate group. In related species and even in the same species at times the intensity of this character is very variable and in individuals may practically disappear. For example, in *arenarius* the rays while hygroscopic are usually pliable and thin, while in the very closely related *floriformis* they are much more rigid. In *asper* individuals appear rarely without any hygroscopic tendency at all, though the species is markedly hygroscopic (see p. 216).

Within certain limits the structure of the mouth area is the most dependable character. The sulcate group is a natural one and there are no confusing intermediates connecting it with the non-sulcate group. So-called intermediates like *Morganii* are not troublesome, as their crumpled mouths rarely bear any real resemblance to a truly sulcate peristome. In the non-sulcate group the distinction between the definite and indefinite peristome, while adequate enough as a rule, is in some cases obscured by variation. This is particularly true in *floriformis* and *arenarius*. In constructing the key we have used the characters in the order of their importance as it seems to us, and the key is therefore as natural a grouping of the species as we can arrange at present.

Numbered collections are all from Chapel Hill unless otherwise stated. The ink drawings were made by Miss Alma Holland and in all cases compared with the preparations by the author.

IMPORTANT LITERATURE

DESTREE, CAROLINE. Révision des Geaster observés dans les Pays-Bas. Nederlandsch Kruidkundig Archief, 2nd. ser., 6: 488. 1895.

DE TONI. Revisio monographica generis Geasteris, Mich. Rev. Myc. 9: 61, 125 pl. 2. 1887.

LLOYD. The Geastrae, figs. 1-80. Cincinnati, 1902.

LLOYD. New Notes on the Geasters. Myc. Notes No. 25: 309, figs. 144-149 and pls. 94-101. 1907.

MORGAN. The North American Geasters. Amer. Nat. 18: 963, figs. 1-12. 1884.

MORGAN. New American Geasters. Journ. Myc. 1: 7. 1885. Condensed from above paper.

MORGAN. Journ. Cin. Soc. Nat. Hist. 12: 12, pls. 1, 2. 1889.

MORGAN. The Genus Geaster. Amer. Nat 21: 1026, figs. 1-2. 1887.

PETRI. Flora Italica Cryptogama (Gasterales), Fasc. 5: 67. 1909.

REA. British Geasters. Trans. Brit. Myc. Soc. 3: 351, pls. 17-19. 1911.

RICK. Die Gattung Geaster und ihre Arten. Bot. Centralb. 27, Abt. II: 375, figs. 1, 2. 1910.

SCHERFFEL. Bemerkungen über Geaster-Arten. Ber. d. Deutsch. Bot. Ges. 14: 312, pl. 19. 1896.

SMITH. British Geasters. Grevillea 2: 76, pls. 13-17 and 19-20. 1873.

SMITH. Two species of Geaster. Grevillea 2: 35, pls. 13 and 14, fig. 1. 1873. 1215 (with text figs., which are reproduced in Grevillea 2).

SMITH. Two species of Geaster. Grevillea 2: 35, pls. 13 and 14, fig. 1. 1873.

TULASNE, L. R. AND C. H. Sur les genres *Polysaccum* et *Geaster*. Ann. Sci. Nat., 2nd. ser., 18: 129. 1842.

WOODWARD. An essay towards an history of the British stellated Lycoperdons. Trans. Linn. Soc., London, 2: 32, 323. 1794.

For other literature see this journal, 38: 232. 1923.

KEY TO THE SPECIES

Peristome not truly sulcate, i. e., not regularly ridged and grooved throughout the extent of the peristome; irregularly wrinkled and crumpled only in *G. Morganii*.

Mouth area distinct as a silky zone of different texture and often of different color, but not outlined by a sharp narrow groove (in *G. subiculosus* the mouth area is scarcely distinct); spore sac without glistening particles and, if stalked, the stalk short and thick; button exposed or, if submerged, the outer coat not holding earth or trash to any extent and the mycelium attached only by the center of the base; expanded plant saccate or convex below or imperfectly to typically fornicate

Rays not hygroscopic, i. e., not incurved over or around the spore sac when dry or expanding when wet

Outer surface smooth and glabrous or with the texture of soft leather (rarely scaly); button with a distinct, narrow point

Outer layer of rays tending to crack into longitudinal strips or less often into irregular plates, slightly if at all separating from the middle layer; base saccate or plane or less often concave below; mouth not wrinkled.....*G. triplex* (p. 175)

Outer layer of rays stripping off on the central region and over the proximal part of the rays and remaining convex below, the inner layer arching upward and elevating the spore sac (pseudofornicate); mouth not wrinkled

G. limbatus (p. 178)

Outer layer and shape of plant as in *G. triplex*, but outer layer tending to peel off in irregular flakes; mouth irregularly wrinkled or crumpled (pseudosulcate)

G. Morganii (p. 180)

Outer layer soft, not cracking into strips, but with some tendency at times to peel from the rays; mouth not wrinkled; plants small (at least in the N. American form)

Spores 3.4-4.8μ thick.....*G. saccatus* (p. 182)

Spores 2.2-3.5μ thick.....Northern form of *G. saccatus*

Outer surface pale buff, nearly or quite glabrous, with the txture of leather; peristome scarcely distinct; dry button blunt, with a low broad umbo, or the top umbilicate; spores smooth, 2-3μ

G. subiculosus, sense of Lloyd (p. 191)

Outer surface not glabrous, but tomentose, strigose or spongy; button not pointed

Plants medium to large; outer surface spongy-tomentose, rather harsh, pale

Expanded plant saccate; spores 2.5-3.3μ...*G. velutinus* (p. 184)

Expanded plant fornicate; spores 3.8-4.8μ..*G. radicans* (p. 186)

Plants small, the base pinched to a point; cespitose or gregarious in numbers from a conspicuous, superficial white mycelium which binds together the twigs and leaves of the substratum

Outer surface brown, strongly tomentose to strigose, at least when young; peristome distinct; spores minutely warted, 3.4-4μ.....*G. mirabilis* (p 188)

Outer surface strongly strigose; spores 3-3.6μ

G. trichifer (p. 191)

Rays hygroscopic

Plants of medium size; outer peridium clean of dirt even in the button

G. mammosus (p. 193)

Plants small, covered with sand all over at first

G. arenarius (p. 195)

Mouth area not distinct, at least without a definite boundary (at times the color is paler or darker, and a depressed zone may be present in *G. floriformis*); button quite submerged; outer surface covered with flocculent mycelium holding trash or sand; plants saccate or fornicate or intermediate

Rays not hygroscopic

Spore sac asperate with stiff hairs.....*G. Hieronymi* (p. 198)

Spore sac not asperate

Outer peridium with center elevated to expose the spore sac, which is short stalked or sessile

Mycelial (outer) layer adhering to the center and rays
G. rufescens (p. 196)
Mycelial layer remaining in the ground and forming a hollow cup with the strongly reflexed rays attached to its margin (fornicate) ..... *G. fornicatus* (p. 199)
Outer peridium saccate and enclosing the sessile spore sac like a bowl
G. fimbriatus (p. 200)

Rays hygroscopic
Surface of spore sac spongy..... See *Astraeus* (p. 219)
Surface of spore sac not spongy
Spores about 3.5-4.5μ..... A form of *G. arenarius* (p. 196)
Spores about 5-7μ..... *G. floriformis* (p. 203)

Mouth area very distinct, silky and outlined by a narrow groove; buttons quite submerged until dehiscence, and the outer layer covered with earth or trash; expanded plants concave below and often truly fornicate; spore sac with a slender stalk and covered when fresh with minute, glistening particles; rays not hygroscopic
Plants of small to medium size, growing on the ground or on humus; spores dark brown..... *G. coronatus* (p. 205)
Plants small to very small, growing on mossy trunks of living trees; spores very pale..... *G. leptospermus* (p. 209)

Peristome truly sulcate with regularly arranged ridges and grooves composing the peristome; all U. S. American species (at least) with buttons submerged until dehiscence
Not hygroscopic, the rays bent backward, the base concave below; spore sac stalked or sessile

Peristome not black
Plants of medium size, stalk long, lower part of spore sac often striate radially; spores about 4.2-5.5μ..... *G. pectinatus* (p. 210)
As above but spore sac not striate and having a flaring collar pendent around its lower side..... *G. Bryantii* (p. 212)
Plants small; stalk short; spores about 3.7-4.4μ.. *G. Schmidelii* (p. 213)
Peristome black or nearly so; spore sac sessile..... *G. Hariotii* (p. 214)

Hygroscopic, the rays bent inward (typically) when dry, spreading when wet
Spore sac covered with rather coarse, wart-like particles, short stalked
G. asper (p. 215)
Spore sac minutely furfuraceous, smooth in age, sessile
G. umbilicatus, sense of Morgan (p. 217)
Spore sac minutely spiny to pulverulent-granular, sessile
G. Drummondii (p. 218)

Geaster triplex Jung.
G. Michelianus W. G. Smith

PLATES 18 AND 35

Plants large, pointed before opening, the point up to 12 mm. long, the inner peridium subspherical, up to 2.7 cm. thick, quite sessile, gray-brown when fresh, becoming reddish brown with age; mouth fibrillose and becoming lacerated, surrounded by a more or less definitely outlined, broadly conical area which may or may not be paler. Outer peridium splitting into 6-8 segments with long acuminate tips which expand or become revolute under the convex, flat or less often arched base; fleshy layer thick, in our plants mostly remaining intact as a moderately thick, reddish brown, cracked crust on the fibrous layer, the central region in some plants breaking loose from the part on the rays to form a broad collar or cup around the inner peridium; outer layer usually nearly free of dirt or trash, but with a few small particles sticking to any part, firm, glabrous, dull yellowish, mostly adnate, but cracking into radial strips or irregular areas; mycelium basal and leaving a scar at point of attachment when the plant is lifted; button supposed to be sunk in the substratum, but its surface does not hold the trash as in *G. fimbriatus*, *G. rufescens*, *G. fornicatus*, and most other subterranean species (for rare exception see note under Alabama entry below). Columella about 1 cm. long, clavate, and persistent.

Spores (of No. 5886) deep smoky brown, distinctly warted, spherical, 3.7-4.4μ, most about 3.9μ thick. Capillitium threads unbranched, about 5μ, up to 6μ thick, not sinuous, concolorous with the spores.

Geaster lageniformis, as suggested by Morgan (see Lloyd, The Geastrae, p. 38), is a small form of *G. triplex*. The cracked surface, definite mouth, pointed button, and spores are all the same. A typical-looking plant of *G. lageniformis* from London, Canada, (N. Y. Bot. Gard., labelled *G. saccatus*) has spores distinctly verrucose, 3.5-4.2μ. Another from the same place and in the same herbarium is Ellis & Ev., N. Am. Fungi, No. 2735 (as *G. triplex*). Our plants are like the *G. triplex* of Thümen's Mycotheca Universalis No. 1410 from Holland, which has spores distinctly papillate, 3.6-4.2μ. Plants from Hungary at the New York Botanical Garden correctly labelled *G. lageniformis* are the same, with spores verrucose, 3.4-4μ

PLATE 18

GEASTER TRIPLEX. No. 682.

thick. Similar plants from Hungary also labelled *G. lageniformis* are in the Herbarium of the Museum of Paris. Another example from Charlottenburg in the same herbarium (P. Sydow, coll., as *G. fimbriatus*) has spores distinctly verrucose, 3.7-4.5μ. In American herbaria one often finds under *G. lageniformis* plants that we are referring to *G. saccatus*, northern form.

Illustrations: Clements. Minnesota Mushrooms, fig. 89.
Destrée. l.c., pl. 9, fig. A.
De Toni. l.c., pl. 63, fig. C.
Hard. Mushrooms, pl. 66.
Hollos. l.c., pl. 11, figs. 1-6 (these figs., if correct, represent a very coarse form); pl. 29, fig. 17.
Lloyd. The Geastrae, figs. 47-49. Also pl. 94, figs. 1-5.
Massee. Ann. Bot. **4**: pl. 1, fig. 27 (as *G. Michelianus*).
Micheli. Nova Plant. Gen., pl. 100, fig. 1.
Morgan. Amer. Nat. **18**: fig. 2.
Petri. l.c., fig. 38.

Illustrations of the form *G. lageniformis:*

Hollos. l.c., pl. 10, figs. 13 and 14. Figs. 11 and 12 more nearly represent what we are calling *G. triplex*.
Lloyd. The Geastrae, figs. 76 and 77.
Petri. l.c., fig. 37, 7.
Smith. Grevillea **2**: pl. 20 (as *G. saccatus*).
Vittadini. Monog. Lycoperd., pl. 1, fig. 2.

682. Chapel Hill, December, 1908. Old collection with no other data.
5886. On mossy oak stump, October 17, 1922.
Asheville. Beardslee.

South Carolina. Ravenel. (Curtis Herb., as *G. fimbriatus*, No. 3025, and as *G. saccatus*, No. 1600; Path. and Myc. Herb., as *G. saccatus*, Fung. Car., No. 77). Another folder of this No. 77 is a smaller plant with softer felted outside and tapering lobes and looks like our *G. saccatus* from Asheville.

Alabama. Spring Hill. Bertolet, coll. (Lloyd Herb.). Some of these have clean surfaces, while in others the surface is as dirty and trashy as in *G. rufescens*. Mouth very definite.

New Jersey. Pennsville. Sept., 1891. Ellis and Everhart, N. Am. Fungi, No. 2736. (N. Y. Bot. Gard. Herb., as *G. fimbriatus*). This is good *G. triplex*. (Path. and Myc. Herb., Washington, as *G. striatus*).

Pennsylvania. New Garden. (Michener Herb., as *G. rufescens*).

Ohio. Loveland. James, coll. 1880. (Path. and Myc. Herb., as *G. saccatus*). Outer surface mottled as in Rick, No. 261.
Cincinnati. Spurlock, coll. (Path. and Myc. Herb., as *G. lageniformis*). Also collection by James in the same herbarium.

Missouri. St. Louis. Trelease, coll. (Farlow Herb.). *Lageniformis* form.

Wisconsin. Algonia. Dodge, coll. (Univ. Wis. Herb. and U. N. C. Herb.).
Madison. Trelease, coll. (Farlow Herb.). A small, papery form.

Washington. Seattle. Murrill, coll. (N. Y. Bot. Gard. Herb., No. 208). With a long single root, 2-3 mm. thick, attached to center of base and branched below.

Canada. London. Dearness, coll. (Path. and Myc. Herb., U. N. C. Herb., also Ellis and Everhart, N. Am. Fungi, No. 2735 in N Y. Bot. Gard. Herb.).

Mexico. Colima. Murrill. January, 1910. Several buttons show a small point with top collapsed around it; surface hard and glabrous, in some cases with flat, more or less inherent scales like *Scleroderma vulgaris*, nearly clean; peristome distinct. Such a form is shown by Lloyd, Myc. Notes, p. 339, fig. 166.

South America. Paraguay. Balansa, coll. (N. Y. Bot. Gard. Herb., unnamed). Spores 3.7-4.2μ.

Brazil. Rick, coll. Fungi Austro-Americani, No. 261. (Path. and Myc. Herb., Washington). Exactly like *G. triplex* except that the outer surface is cracked and mottled to remind one of a giraffe, a form closely approached by the plant from Ohio cited above. Spores 3.5-4.1μ thick, surface as in *G. triplex*.

Venezuela. Fendler, coll. (N. Y. Bot. Gard. Herb., as *G. saccatus*). Looks exactly like *G. triplex*. A large plant with spore sac 2.5 cm. thick; rays long and taper-pointed. Spores distinctly warted, 3.7-4.4μ thick.

England. Surrey and Ascot. (N. Y. Bot. Gard. Herb. from Massee Herb., as *G. Michelianus*).

Geaster limbatus Fr. Sense of Bresadola.

PLATES 19, 35, AND 36

Plants large and resembling *G. triplex* in most important characters. The following description refers to the dried plants: Outer peridial surface firm, glabrous, nearly clean of trash except at base, mycelium attached only at a central point below; rays reflexed, the long tapering tips usually revolute; outer layer not cracked into strips or flakes, but separating as a rule from the central region and the proximal part of the rays, and remaining convex below while the inner layer arches upward and elevates the spore sac (pseudofornicate). Spore sac subglobose with a more or less obvious apophysis, brown, nearly glabrous and with a short, thick, often flattened stalk; peristome definite, silky, often paler than the sac, broadly conical, the mouth fimbriate. Fleshy layer brown, rather thick, mostly adnate and not cracking. Columella subspherical, about 4-5 mm. thick.

Spores (of plant from Wisconsin) spherical, distinctly warted. 3.7-4.8μ, most about 4μ thick. Capillitium threads straight, not branched, concolorous with the spores, up to 7μ thick.

PLATE 19

GEASTER LIMBATUS. Burlington, Wisconsin [lower right].
Kansas, No. 8252 [other three].

This plant is evidently nearly related to *G. triplex* as shown by long-pointed lobes (indicating a pointed button), absence of flocculence on the outer surface, which is clean and glabrous in large part, and in the definite mouth and similar spores. It differs from *G. triplex* in the splitting away of the outer layer over the central region and the arching up of the middle layer. The stalk is probably no more obvious than it would be in *G. triplex* if it were to assume such a position.

There is much confusion among authors and in herbaria as to the identity of *G. limbatus*. This is the only American plant labelled *G. limbatus* in American herbaria which cannot be referred to *G. triplex* or *G. rufescens* or *G. pectinatus*. Most of the collections at the New York Botanical Garden labelled *G. limbatus* are *G. rufescens*, e.g., from Alabama, Kentucky, Ohio, Missouri, Indiana, Colorado and Canada. All the material in the Path. and Myc. Herb. at Washington as *G. limbatus* is *G. rufescens*, as Ellis, N. Amer. Fungi, No. 1309, and others from Ohio and Colorado. Morgan figures a plant as *G. limbatus* (N. Amer. Geasters, fig. 6) which is probably *G. rufescens*, as noted by Lloyd and Hollos. A plant in the Curtis Herbarium from Alabama as *G. limbatus* (Peters, No. 934) is *G. rufescens* with a short stalk. We are adopting the name of *G. limbatus* for the present species as it is so determined by Bresadola, as shown by a European specimen from him in the Lloyd Herbarium. This has exactly the habit of the American plant described above, the outer surface clean and separated from the fibrous layer over the center and proximal part of the rays. Another plant from Bresadola so labelled has the outer surface earthy and not separated in part. The mouth is distinct in both. Our plants described above are also the *G. limbatus* of Lloyd, at least in so far as the American specimens are concerned, as shown by a number of plants in his herbarium. Among Lloyd's illustrations of *G. limbatus* (The Geastrae, figs. 42-46), figs. 45 and 46 represent the species as we have it. His three other figures are probably not the same. Figure 42 of a plant from Rea (England) and fig. 44 of a plant from Hollos (Hungary) apparently represent the dark species noted below and considered *G. limbatus* by English authors and by Hollos.

It is certain that the *G. limbatus* of Hollos and of Massee and Berkeley and to all appearances that of Elias Fries* is not our plant,

* In the Curtis Herbarium are two plants from E. P. Fries (Upsala) labelled by him *G. limbatus*, but they are really *G. pectinatus*. Worthington G. Smith gives a figure (Grevillea 2: pl. 17, fig. 2) as *G. limbatus* which has all the appearance of *G. pectinatus* except that grooves are not shown on the peristome.

and we have never seen anything like it in this country. It is a large, usually very dark plant (blackish brown; some forms are paler and glaucous) with a short thick stalk, a large, definite, fimbriate mouth of more brownish tint and with a universal flocculent covering that holds earth tightly as in *G. rufescens.* In fact, the appearance is very much that of *rufescens* except for the blackish and more glabrous spore sac and more definite mouth. It is beautifully shown in Hussey's Illustrations, pl. 2. Good plants from Hollos in the Farlow Herbarium and from Massee (determined by Berkeley) in the New York Botanical Garden Herbarium are alike. The former has spores which are distinctly warted, 4-5.2μ thick, and with which those of the latter agree (4.2-5.5μ). Another plant from Massee (Chiselhurst) so labelled is the same. Plants from Germany (Berlin; Magnus, coll.) labelled *G. rufescens* by the collector are also the same: nearly black, mouth distinct. The outer surface of this blackish plant of Northern Europe is quite different from that of our plant, and it does not peel off. Neither Hollos nor any other European author mentions the separation of the outer layer in *limbatus.* The spores as given by Hollos are 4-5, often 6μ thick, which is too large for our plant. *Geaster pseudo-limbatus* is represented from Hollos in Lloyd's Herbarium and apparently does not agree with either idea of *limbatus* discussed above.

Illustrations: Lloyd. The Geastrae, figs. 44 and 45.

New York. Syracuse. Oct. 1888. Underwood, coll. (N. Y. Bot. Gard. Herb; also a small form as *G. Schaefferi*).

Massachusetts. South Hadley. 1888. Hooker, coll. (N. Y. Bot. Gard. Herb.).

Kansas. Bartholomew, coll. (N. Y. Bot. Gard. Herb., No. 2215; U. N. C. Herb., No. 8252). Spores of No. 8252 are 3.4-4μ thick.

Wisconsin. Burlington. (Univ. Wis. Herb. and U. N. C. Herb.).

Minnesota. Miss Hone, coll. (N. Y. Bot. Gard. Herb. and Lloyd Herb.). Spores dark, distinctly warted, 3.5-4.2μ, most about 4μ.

Colorado. Brandegee, coll. (N. Y. Bot. Gard. Herb.).

Canada. Macoun, coll. (N. Y. Bot. Gard. Herb.).
London. Dearness, coll. (U. N. C. Herb.). Spores 3.6-4.2μ.

Geaster Morganii Lloyd

PLATE 35

Button broadly bulb-shaped with a short to rather long point (up to 6 mm.), yellowish, the base flat; mycelial attachment from a central basal point, the surface nearly or quite clean, buffy alutaceous, dull, felted to minutely spongy; rays about 7-10, taper-pointed, pliable, the outer layer tending to crack and peel off in irregular flakes (more separable than in typical *triplex* or *lageniformis*); fleshy layer dark brown to blackish, cracking and at times forming a collar as in *G. triplex;* spore sac sessile, sub-spherical, usually compressed when dry, minutely granular-felted, wearing glabrous, brown; peristome rather vaguely outlined, forming a narrowly conical papilla (typically) with the sides crumpled toward the top or almost all over, forming a pseudo-sulcate peristome with lacerated tip.

Spores (of a plant from Ohio; Underwood, coll.) spherical, distinctly warted, 3.4-4.1μ thick. Capillitium threads wavy, up to 7μ thick.

The plant seems common in the middle west, less so elsewhere. We know of no record for the southern states, but there is in the Curtis Herbarium a plant from Alabama (Peters, No. 198) as *G. saccatus* that we believe to be this species. The mouth is very long and narrow and not at all like *triplex,* but is not crumpled. Lloyd mentions such a mouth as occurring. The nearest relative seems *G. triplex,* which differs in even mouth and smooth outer surface. Lloyd now considers his *G. Morganii* a synonym of *G. Archeri* Berk. (Hooker's Fl. Tasm. 2: 264, pl. 183, fig. 9 bis. 1860) but compared with American *G. Morganii,* the lobes of *G. Archeri* are more slender and tapering, and the outer surface differs in not being cracked. The fleshy layer looks quite different and has a hard, cartilaginous appearance with few cracks, instead of the softer, more leathery appearance of the rimose fleshy layer in *G. Morganii.* The spores are the same. The type material of *G. Archeri* at Kew consists of two separate mounts of one open plant each, both from Tasmania (Archer, coll.). The plants have long, tapering and twisted lobes, rather pliable; fleshy layer thin, continuous; outer layer with texture of leather, not cracked in radial lines; spore sac deep brown, glabrous, mouth apparently as in *G. Morganii,* but somewhat obscured by pressure. Spores (of No. 28) spherical, regularly warted, 3.4-4μ thick (pl. 36, fig. 14).

Illustrations: Lloyd. The Geastrae, figs. 31-36.

Morgan. North Amer. Geasters, fig. 3 (as *G. striatus*).

Massachusetts. Peabody. Mackintosh, coll. (Lloyd Herb.). Fine lot with buttons.

Ohio. Underwood, Morgan, Lloyd, and James, colls. (All in the N. Y. Bot. Gard. Herb.).

Columbus. Brewer, coll. (Lloyd Herb.).

Cincinnati. Lloyd, coll. (Lloyd Herb.).

Dinwood. Lloyd, coll. (Lloyd Herb.).

Indiana. Underwood, coll. (N. Y. Bot. Gard. Herb.).

Delaware. Commons, coll. (N. Y. Bot. Gard. Herb.).

New York. Chippewa Bay. Phillips, coll. (Path. and Myc. Herb.). Spores minutely waretd, 3.4-4μ thick.

Geaster saccatus Fr.

PLATES 20 AND 35

Plants saccate, of medium size or rather small, the expanded rays with a spread of 2.5-4 cm. (see note on a larger form below); buttons subglobose with a point up to 4 mm. long, or rarely with only a rounded umbo. Mycelium strictly basal and radicating by flocculent strands from a central basal point; outer surface felted or nearly smooth, almost clean or at times with a few bits of rotten wood or leaves, not cracking, with some tendency for the outer layer to separate on the rays which are 6-9, pliable, thin, expanded, with the tapering tips revolute; fleshy layer reddish brown, thin, adnate, somewhat cracked. Spore sac 10-13 mm. broad, sessile, surrounded below by the saccate base, smooth, brownish drab to gray-drab; peristome silky, paler or nearly concolorous, distinctly or rather vaguely limited. Columella not obvious.

Spores spherical, dark, minutely but distinctly warted, variable in size, those of the U. S. American plants running smaller, e.g., in an Asheville plant 2.2-3.3μ, in a Jamaica plant 3.7-4.8μ. Capillitium threads about the color of the spores or paler, 5-7.5μ thick.

Gregarious on leaves of deciduous trees with a tendency to crowding, which is more or less obvious in most collections. Apparently rather rare. We have not found it at Chapel Hill.

The plant cannot be distinguished by absence of a pointed button when dry, though the point is not so long as it usually is in *G. triplex* forms. Buttons in the same collection may vary from slightly

PLATE 20

GEASTER SACCATUS. Asheville, N. C. [above].
GEASTER MIRABILIS. No. 7077 [below].

umbonate to pointed like our photograph of the Asheville collection. Hollos as well as Morgan, Trelease, and Lloyd include our U. S. American plant in *G. saccatus*. Hollos separates it correctly from *G. lageniformis* by its soft outer peridium which is usually free from trash. It is further separated from that species which has a firm, hard outer surface by the absence of longitudinal surface cracks that are usually present in the latter, and (at least in the U. S. American form) by the smaller and less rough spores. Hollos is wrong in considering *G. velutinus* the same as *G. saccatus*. The former is very easily distinguished from *G. saccatus* by its larger size, firmer, harsher, paler, more spongy-looking and more separable surface layer.

At the New York Botanical Garden is a collection that we take to be this (Gentry, coll. Two buttons and an open plant; no data). The buttons are larger than in the others, 2.2 cm. thick and up to 2.6 cm. tall including the point, which in one is about 1 cm. long, in the other about 4 mm. Surface layer soft and felted, very clean except on the base, separating in places from the middle layer; mycelium attached to a basal point. Spore sac sessile, mouth very distinct. Spores spherical, minutely warted, 3-3.6μ thick.

There is still some doubt as to what the true *G. saccatus* is. As Fries described it, it is obviously in the *G. triplex* rather than in the *G. fimbriatus* series, as indicated by the radicating, basal mycelium and the clean or trashy, adnate, soft, leather colored outer surface, and long, narrow points of the rays. Authors and collectors have referred to *G. saccatus* both *G. triplex* (including the *lageniformis* form), and *G. fimbriatus*, as well as the plant that we are calling *G. saccatus*. Lloyd confuses the latter two in American and has also referred the *lageniformis* form of *G. triplex* to *G. saccatus* (see plants at the New York Botanical Garden, sample box). Morgan distinguishes them properly by the difference in the mouth, but fails to call attention to the difference in the outer surface which is at least as important. Rick has distributed from Brazil as *G. saccatus* two quite different plants: one (Fungi Aus.-Amer., No. 330) which looks just like *G. fimbriatus*, with flocculent trashy outer surface and indefinite mouth. The spores, however, are distinctly larger than in *G. fimbriatus*, faintly warted, 3.8-4.6μ thick. Another (Fungi Aus.-Amer., No. 261) is just like our *G. triplex*, except that the outer surface is cracked in a mottled way rather than in radial lines (spores 3.5-4.1μ). This mottled cracking may also be noted in U. S. American *G. triplex*

(as plant from Loveland, Ohio, noted under that species). Rick's figure of *G. saccatus* (Broteria **5**: pl. 2, figs. 6 and 8) shows a little plant with distinct mouth and clean surface that looks just like the plants we are calling by that name. What Spegazzini distributed from Argentina as *G. saccatus* (Dec. Myc. Arg., No. 44) is a hygroscopic plant with an indefinite mouth and about the size of *G. mammosus*. It is evidently not the Friesian species. (This is noted also by Lloyd.) In the Lloyd Herbarium there are two collections of *G. saccatus* from Berlin (Magnus, coll.). They are like ours, with surface nearly or quite clean, peeling off to some extent from the tips of the rays.

Illustrations: Hollos. l.c., pl. 10, fig. 19.
Lloyd. The Geastrae, fig. 75b.
Rick. Broteria **5**: pl. 2, figs. 6 and 8.

North Carolina. Asheville. Beardslee, coll. 1917. (U. N. C. Herb.).

Florida. New Smyrna. Sams, coll. (Lloyd Herb.).

Maryland. Plummer's Island. P. L. Ricker, coll., 1922. (Path. and Myc. Herb., Washington).

Ohio. Lloyd. (N. Y. Bot. Gard. Herb., 2 colls.). Spores of one collection minutely rough under high power, 2.3-3.1μ thick; in the other, 3-3.5μ thick.
Also E. & E., North Amer. Fung., No. 3417. (Path. and Myc. Herb.).
Cincinnati. Aiken, coll. (Lloyd Herb.).

Kansas. Fort Scott. On leaf mold, July, 1902. Garrett, coll. (N. Y. Bot. Gard. Herb., no name). Cespitose, small, soft, surface felted. Exactly like Lloyd's plant from Ohio.

Missouri. St. Louis. Glatfelter, coll. (Lloyd Herb.).

Canada. London. Dearness, coll. (U. N. C. Herb.).

Mexico. Botteri, coll. (Curtis Herb., as *saccatus*).

Porto Rico. Stevenson, coll. (N. Y. Bot. Gard. Herb.). Spores minutely warted, 3.4-3.7μ.

Bahamas. New Providence, September, 1904. Mrs. Britton, coll. (N. Y. Bot. Gard. Herb.).

Bolivia. January, 1902. R. S. Williams, coll. (N. Y. Bot. Gard. Herb.). Spores spherical, minutely but distinctly warted, 3.4-4μ thick.

Jamaica. New Haven Gap, 5600 ft. elevation. Murrill, coll. January, 1909. (N. Y. Bot. Gard. Herb.).

Cuba. Wright. (Curtis Herb., as *G. saccatus* No. 668 and 870, and as *G. fimbriatus*, the latter with a clean, pointed button).

Geaster velutinus Morg.

G. Readeri Cooke and Massee.

PLATES 21-23 AND 35

Unopened plants seated on the substratum (not embedded in it) and therefore attached to the mycelium only at the base, ovate and bluntly pointed at the top, up to 2.3 cm. broad and 2.6 cm. long. Surface dull and finely felted-tomentose, very much like the surface layer of *Lycoperdon leprosum*. It is flesh color, becoming creamy yellow or buff color on drying. Outer peridium splitting into about 7 reflexed or expanded segments which are a pretty flesh color on the inner (upper) surface when fresh. As these dry they split more or less into two thin, fibrous, persistent layers, a characteristic habit, and usually curl backward under the basal part which remains convex or flat below. Inner peridium smooth, appearing minutely felty under a lens, dark brown or sometimes light gray (when collected perfectly fresh), subglobose, attached by a broad or rather narrow base, almost or quite sessile; mouth small, fibrillose and later lacerated, surrounded by a distinct, radially fibrous, broadly conical, silvery gray or light to dark brown area which is about 5 to 8 mm. in diameter. Columella obvious and clavate in the button; slender and more obscure in the mature plant.

Spores (of No. 4095) spherical, 2.5-3.3μ thick, most about 3μ thick, distinctly asperulate and with a halo, deep smoky purplish brown. Capillitium threads rather large, up to 11μ thick, often branched near the tapering tips.

A rather common, large plant that prefers pine woods. It is easily distinguished by the felted-tomentose outer peridium which splits into two persistent, pliable layers and by having the mycelium attached only at the base, the unopened plant easily visible and often collected before expansion. In many individuals there is plainly to be seen on the under side a circular scar marking the area of attachment. From a part of the type collection of *G. Readeri* from Australia (Grevillea **16**: 73. 1888), at the New York Botanical Garden, it is shown that it is the same as *G. velutinus*, the plants not being distinguishable from the American ones in any way, the surface pale, velutinate, peeling off in part; peristome distinct, size and shape of plant the same; spores spherical, very minutely warted, 2.8-3.3μ thick. There are two other plants mounted in the same herbarium

that are also marked "type specimens." These have some sand on the outer surface, but the spores are the same, 3-3.5μ thick. The plant was first named *G. australis* by Reader, a name previously used by Berkeley. A plant from New Zealand determined as *G. Readeri* by Massee (N. Y. Bot. Gard. Herb.) is not the same. It has the surface more strigose-tomentose and not peeling off, and the spores are distinctly different, warted, 3.8-5μ. The plant distributed by Rick in Fungi Austro-Amer., No. 13, as *G. triplex* is *G. velutinus*.

Illustrations: Hard. Mushrooms, fig. 489.
Lloyd. The Geastrae, figs. 62-71. Also pl. 101, figs. 1-2.

846. In pine woods, October 13, 1913.

999. Under pines in a ravine, October 23, 1911.

1000. Mixed woods on Lone Pine Hill, September 20, 1908. All these plants were unopened.

1260. Under pines in woods, September 24, 1914. Spores 2.7-3μ thick, minutely asperulate. Capillitium threads 3-5.5μ thick, minutely roughened.

1381. In a hollow in woods near Battle's Branch, October 19, 1914. Spores deep purplish brown.

4095. On rotten pine wood, summer, 1919.

7114. On very rotten pine log, September 10, 1923.

7133. In rotting leaves under shrubs in Arboretum, September 22, 1923. Buttons exposed, subspherical, not umbonate when fresh.

7164. In leaves of frondose trees and bushes, September 27, 1923.

7219. Near a rotting log, November 21, 1923.
Asheville. Beardslee, coll.
Statesville. Coker, coll. No. 5499. In pine needles, August, 1922.

Alabama. Auburn. Baker, coll. (N. Y. Bot. Gard. Herb.).

Cuba. Wright, No. 254. (Curtis Herb., no name). Button and open plant.

Porto Rico. J. R. Johnson, coll. (N. Y. Bot. Gard. Herb.). The plant, though saccate, has slipped entirely out of the sheath.

Brazil. Rick. (Path. and Myc. Herb., Washington). Also reported by Sydow (Ann. Myc. **5**: 353. 1907).

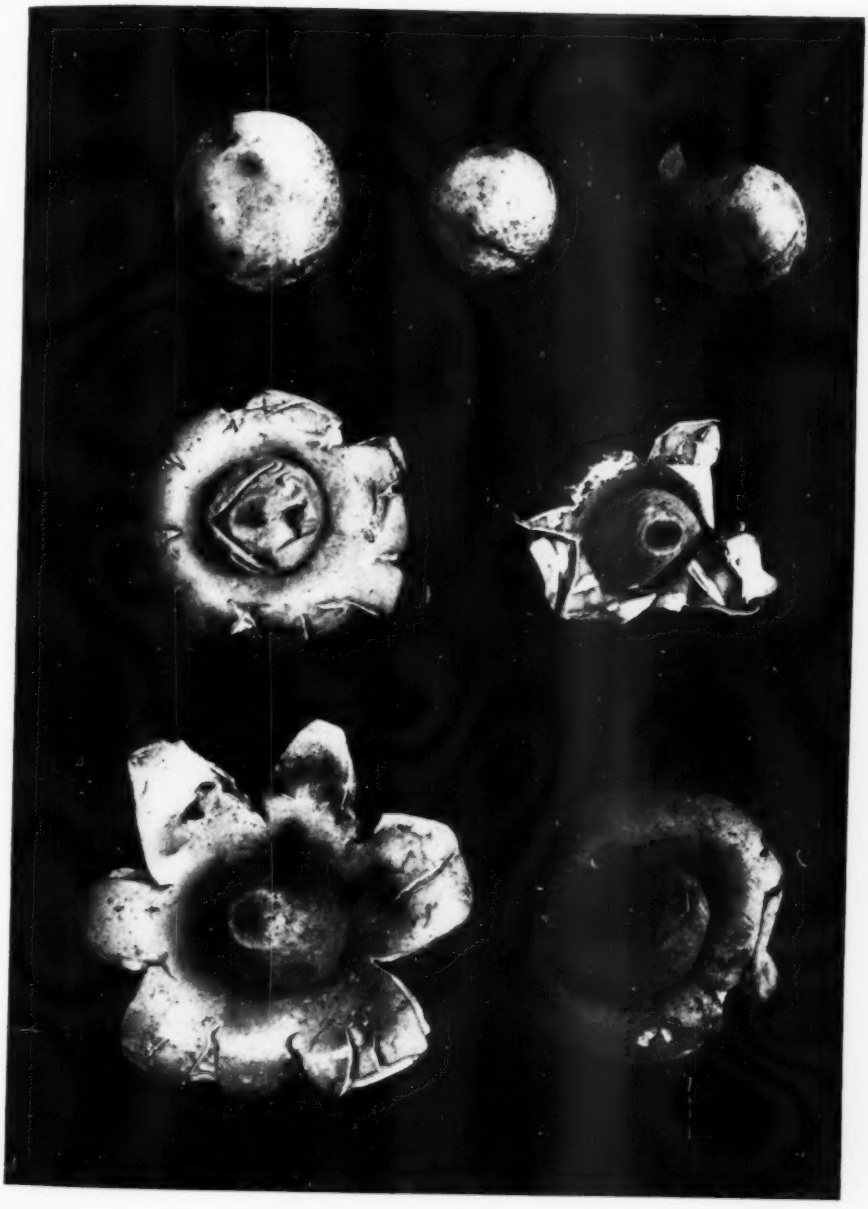
Africa. Uganda. 4000 ft. elevation. Dummer, coll. (Lloyd Herb.). These are buttons which look just like American ones.

Geaster radicans B. &. C.

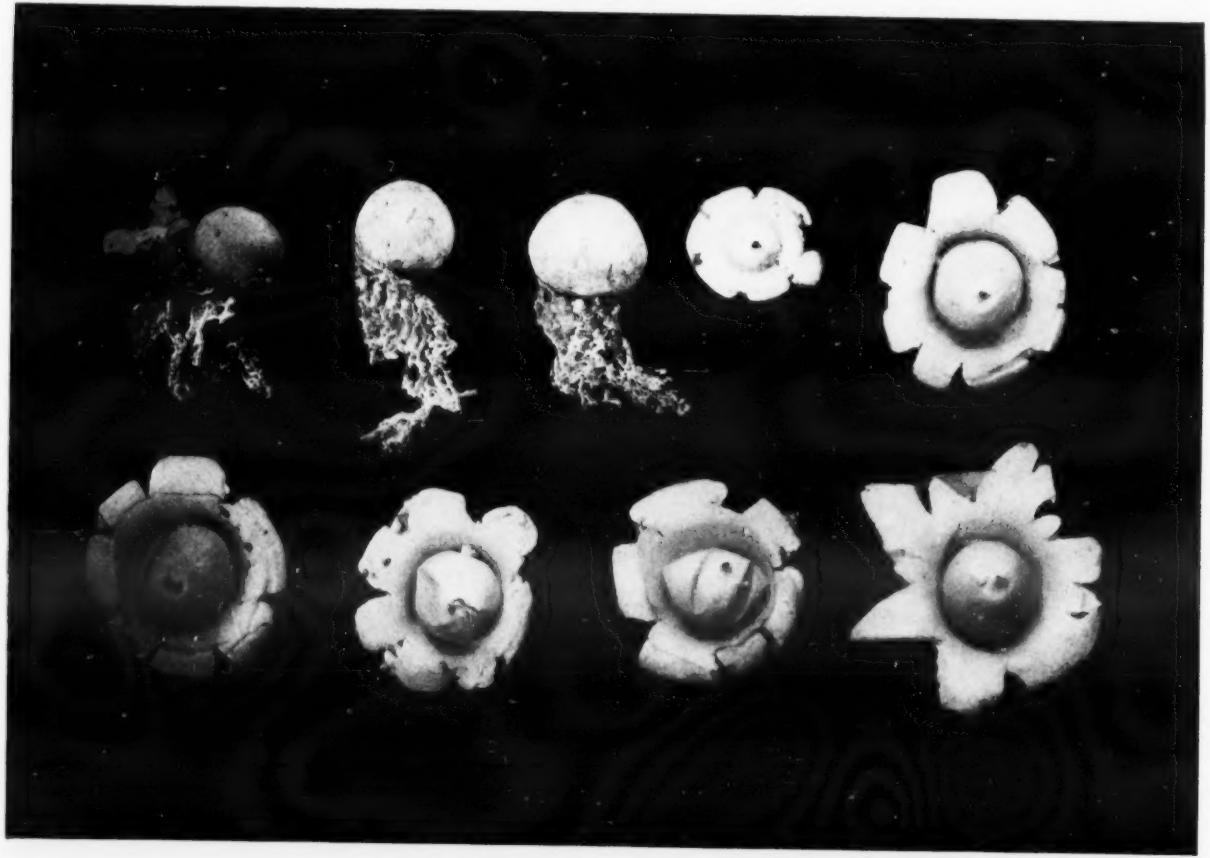
PLATES 35 AND 36

The co-types of *G. radicans* (Grevillea **2**: 49. 1873) in the Curtis Herbarium (as *G. Curtisii*) show it to be closely related to *G. veluti-*

PLATE 21



GEASTER VELUTINUS. No. 846.



GEASTER VELUTINUS. No. 7133.

PLATE 23

GEASTER MIRABILIS. No. 7208 [upper left].
GEASTER CAESPITOSUS. Ohio [upper right].
GEASTER TRICHIFER. Morce's Gap, Jamaica [middle left].
GEASTER SUBICULOSUS. No. 184 [middle right].
GEASTER VELUTINUS (buttons). No. 7219 [below].

nus. In so far as the appearance goes, it is only a fornicate form of that species, as Lloyd says (Myc. Notes, p. 155; The Geastrae, p. 31). There are two mounted plants with basal cups gone and one perfect plant in a box, all Ravenel, No. 953. Ravenel's ms. notes accompany the last specimen. The velutinate outer surface and the felted spore sac are exactly as in *G. velutinus.* A microscopic examination, however, reveals a difference in the spores, which are larger than in *G. velutinus,* 3.5-4μ thick, and more distinctly rough. We have examined the plants from Florida (Sarasota, on a cedar stump) in Washington, one of which was photographed by Lloyd (The Geastrae, fig. 57), and find them exactly like the types, the spores 3.4-4μ thick. The basal cup is a strong, pliable membrane, free from earth, and in no way like the delicate, submerged cup of *G. fornicatus* and *G. coronatus.* We find at the New York Botanical Garden a specimen of this plant from Bermuda, which extends its known range. The spores of this plant are spherical, distinctly warted, 3.8-4.8μ, most about 4.1μ thick. The species is reported as new to Europe by G. Lind in "Danish Fungi as Represented in the Herbarium of E. Rostrup," p. 401, 1913 (no description). Rick figures a plant as *G. radicans* from Brazil (Broteria **5**: pl. 5, fig. 9) that is not fornicate and looks exactly like *G. triplex* with a large collar. He had earlier reported this as *G. triplex,* and says that Bresadola referred his plant to *G. radicans.* It may be *G. velutinus,* but cannot be accepted as *G. radicans.* Lloyd thinks that *G. Welwitschii* (from Spain) is the same as the American plant (Myc. Notes, p. 315, pl. 101, fig. 3).

The Cuban plants reported in the original description as *G. radicans* are represented in the Curtis Herbarium as Wright, No. 873. These three plants are all buttons and are not *G. radicans.* They were entirely submerged and are covered with humus held on by a flocculence as in *G. rufescens;* a single stout basal strand is attached to buttons in two cases; not pointed.

The types were sent to Berkeley by Curtis, who received them from Ravenel, who also sent notes and added that if a new species then "it is *G. Curtisii,*" wishing to honor Curtis. Berkeley, however, ignored this wish of Ravenel's and named it *G. radicans* B. & C. (See Lloyd, Myc. Notes, p. 171). Ravenel in his notes says "with a sulcate-plicate mouth," but the mouth is not truly so as we are defining that character. The best specimen has the mouth pinched into a few crumples, but the others do not show this.

As the usual form and spores distinguish *G. radicans* from *G. velutinus*, we think it well to retain the name, though it would be better to reduce it to a variety.

Illustration: Lloyd. As cited above.

South Carolina. Ravenel, No. 953; Curtis, No. 3041. (Curtis Herb., as *G. Curtisii* Rav., co-types; also in Farlow Herb. from Ravenel).

Florida. Sarasota. On a cedar stump. (Path. and Myc. Herb.).

Bermuda. Millspaugh. (N. Y. Bot. Gard. Herb.).

Geaster mirabilis Mont.
G. caespitosus Lloyd.
G. lignicola Berk.

PLATES 20, 23, 35, AND 36

Densely cespitose to single in considerable numbers, and arising from an obvious white mycelium which binds together the leaves and twigs. Buttons spherical, not pointed, but a few with a small umbo when dry, 0.8-1.2 cm. thick, strigose-tomentose, reddish brown to ochraceous buff, a few blackish; mycelium basal, the buttons quite exposed or partly covered with loose trash (completely covered in No. 7173). Expanded plants 1.4-2.2 cm. wide; lobes usually 6 or 7, expanded (tending to become elevated when dry), the basal half bowl-shaped and holding the completely sessile inner peridium which is 6-9 mm. thick, subspherical, gray, with a delicately felted surface; peristome distinct, silky, more or less elevated, conical, immediately after exposure pale from a granular-looking, minute pubescence, with a darker line around the base, soon darker than the peridium; mouth fimbriated, not sulcate. Fleshy layer when first exposed about 0.5 mm. thick, smooth, light flesh color, soon darker and drying to a thin, adnate, continuous, gray-brown membrane.

Spores (of No. 7077) very dark, minutely warted, 3.2-3.8μ, most about 3.6μ. Capillitium threads sinuous, thick-walled (practically no lumen), much paler than the spores, about 3.4μ thick, the tapering ends smaller.

From *G. saccatus* the present species is distinguished by cespitose habit, much smaller size, hairy surface, less pointed buttons when dry and larger spores. Both have the habit of growing exposed (epigeal).

PLATE 24

[Top row] GEASTER HARIOTII. Brazil (left); Porto Rico (middle); British Honduras (right).

[Second row] GEASTER CAESPITOSUS. Type (left); G. ARENARIUS. Type (right).

[Third row] GEASTER FLORIFORMIS. Grasmere, Florida (3 tiny plants); Denton, Texas (2 larger plants in middle); North Dakota (one plant on right).

[Bottom row] GEASTER ASPER. Long Pine, Nebraska.

The species was originally described from French Guiana and is known also from Brazil, Africa, and the Orient.

Our plants are the same as plants received through the kindness of M. Patouillard and collected in Brazil by Rick. The young buttons have the same strigose-tomentose surface; the older ones more felted-tomentose; spores exactly as in our plants, faintly warted, 3.4-4μ thick, not like the smooth and smaller spores of what we are calling *G. subiculosus*. Rick considers *G. trichifer* the same (see Myc. Notes, p. 804), but Lloyd thinks it different (see that species). In our No. 7077, some of the plants are apparently as strigose as *G. trichifer* (which see), while others show only a matted tomentum, exposure to weather having a considerable effect.

The species is represented in the Kew Herbarium by five cards of material: three from Cuba (Wright), two from Ceylon (G. H. K. T.), and one from Uganda, Africa, (Dümmer, No. 1462). All these have the spores of *G. mirabilis*, and in appearance are the same as the Chapel Hill and Brazilian specimens except that none shows quite so strigose a surface. The spores of the plant from Ceylon, No. 184, are 3.2-3.8μ thick, minutely rough. The African plants connect up directly with *G. papyraceus*, with outer peridium more papery-looking than in the others. The spores of this collection are 3.5-4.2μ thick, with surface as in the others.

Geaster papyraceus B. & C. (Proc. Amer. Acad. Arts and Sciences 4: 124) in the Curtis Herbarium from Japan and Bonin Islands (authentic, but not type) is closely related if not the same. The Japanese plants are all open; peridium extremely thin and papery, pliable, pale creamy straw color, outer surface with a concolorous coat of very thin soft weft in places. Mycelium membranous; fleshy layer almost all gone; inner peridium broken or worm eaten, peristome not shown. The Bonin Island plants are strigose-hairy outside; two cespitose buttons, one grown button apparently torn open at the top, and one open plant; even the last is strigose. These look like *G. mirabilis*. Fleshy layer intact and rays much stiffer than in the Japanese plants. Peristome distinctly silky. A microscopic examination, however, shows the spores to be identical in the two collections. In the Japanese plants they are spherical, finely but distinctly warted, 3.5-3.8μ thick, with a very distinct and shiny oil drop. In the Bonin Island plants they are 3.6-4μ thick, surface and oil drop as in the others. We can confirm Lloyd's opinion (Myc. Notes, p. 181) that

Coilomyces Schweinitzii B. & C. is an unopened *Geaster* related to, if not the same as, *G. mirabilis*. The plants in the Curtis Herbarium have spores exactly like our Chapel Hill *G. mirabilis*, spherical, minutely warted, 3-4μ thick (pl. 36, fig. 15).

Geaster caespitosus is apparently the same, with the usual slight variations which are to be expected. The ample type collection in the Lloyd Herbarium has the exact appearance of our plants except that the strigose character is not so obvious. The surface is softly felted, becoming smoother; peristome silky, sharply defined by a ridge; the plants attached by a pointed base to the abundant mycelium. Spores slightly smaller than in our collections, very minutely warted, 2.3-3.4μ. We find at the New York Botanical Garden a box of miscellaneous material without names but labelled Ohio, Lloyd, No. 255, in which, mixed with three other species, is a dense clump of small plants that are *G. caespitosus* and just like the types. The type of *G. lignicola* Berk. (Journ. Linn. Soc. Bot. **18**: 386. 1881) at Kew from Rockingham, Australia, (Thozet, No. 908) is apparently not different from *G. mirabilis*. There are two crushed buttons and one open plant on fragments of plant material. Mycelium not very obvious; surface of both buttons and mature plants nearly smooth. Spore sac dark brown with fimbriate mouth. Peristome characters not obvious on account of the way the plant is pressed and glued down. Spores spherical, minutely warted, 3.2-4μ thick.

Illustrations. Lloyd. Myc. Works, pl. 100, figs. 2 and 3; also figs. 6-9 (as *G. caespitosus*).

Rick. Broteria **5**: pl. 4, fig. 3. 1906. Freshly opened plants.

7077. On trash and leaves of deciduous trees and a few pine needles, wooded hillside, August 10, 1923.

7173. Under cedars at "The Rocks," September 26, 1923. Buttons subspherical, some with a small umbo when dry; covered up but coming out nearly clean, thus differing from *G. fimbriatus*. Spores minutely warted, 3.2-4.1μ thick.

7208. In rich, rocky soil near cedars, November 11, 1923.

Ohio. Lloyd. (N. Y. Bot. Gard. Herb., unnamed).

Kansas. Cragin, coll. (N. Y. Bot. Gard. Herb., as *G. saccatus*). Outer surface clean, tomentose; spread when expanded 1.8 cm. Spores minutely warted, 3.5-4.2μ.

Cuba. Wright, No. 696. (Curtis Herb.). Button very small, strigose to tomentose.

Jamaica. Bancroft. Ellis, coll. (Farlow Herb.).

Brazil. Rick, coll. (U. N. C. Herb.).

Geaster trichifer Rick

PLATES 23 AND 35

Plants gregarious to cespitose; buttons exposed, subspherical to oblong, pinched below to a point and attached to ropy mycelium, slightly umbonate above, buffy straw color, covered with more or less fascicled hairs about 1 mm. long; rays about six, splitting to or below the middle and tending to remain upright or with tips spreading; outer layer showing a distinct tendency to peel off the rays as in *velutinus*, but less so); fleshy layer leather color, thin, adnate. Spore sac subglobose, sessile in the cup-shaped base, grayish brown, glabrous; peristome very distinct, flat with elevated center, mouth becoming fimbriate.

Spores very minutely rough, 3-3.6μ thick.

Murrill's notes on the fresh condition say "Outside with long, stiff hairs, ferruginous-fulvous, shaggy-setose . . . fleshy layer dirty white; spore sac flattish acorn-shaped, avellaneous . . . Spread 5 cm., center 2 cm." One of the largest plants is now broadly spread and reaches 4 cm., the smaller ones if spread would be about 3 cm. The plants are growing on leaves and twigs and have the habit and shape of *G. mirabilis*, which differs from the Jamaica collection in being much smaller, less strigose, with outer layer not peeling, and in the smaller spores.

The original plants were collected by Rick in Brazil. He now considers it a form of *G. mirabilis*, while Lloyd thinks it different. The plant shown in Lloyd's photos are not larger than *G. mirabilis*, and in fig. 1251 the surface does not appear more shaggy than in *G. mirabilis*.

Illustrations: Lloyd. Myc. Notes, p. 314, figs. 147, 148, and p. 804, fig. 1251.

Jamaica. Morce's Gap. Murrill, coll. No. 739. (N. Y. Bot. Gard. Herb. and U. N. C. Herb.).

Geaster subiculosus Cooke and Massee (sense of Lloyd)

PLATES 23, 35, AND 36

Plants with the habit of *G. mirabilis*, crowded and springing from copious, white, felted mycelium which binds together the leaves, twigs, and sticks on which they grow. Buttons 9-11 mm. broad, com-

pletely exposed, obovoid, pinched below to a point connecting with the mycelium; apex concave by collapse, not pointed. Surface pale buff, wrinkled, glabrous, but with the soft appearance of leather; tardily opening by 6 or 7 rays, the sinuses extending into about a third of the peridium, leaving the basal part unchanged as a deep cup enclosing the sessile spore sac. Fleshy layer drab brown, thin, adherent, not cracked except across the bottom of the rays. Spore sac 1 cm. broad, subspherical, glabrous, brown. Peristome not distinctly outlined or distinctly silky, fading into the sac surface about as in *G. fimbriatus;* mouth scarcely elevated, the opening fimbriate.

Spores (of Jamaica plant) spherical, smooth, 2-3μ thick.

This is clearly distinguished from *G. mirabilis* Mont. by larger size, absence of tomentum, obscure peristome, and smooth and much smaller spores. Even very young buttons are practically glabrous and nearly white. The plant described above is certainly the same as that illustrated by Lloyd in Lycoperd. Australia, etc., fig. 19 and Myc. Works, pl. 100, figs. 4 and 5. He refers to it as *G. subiculosus*, which he considers a form of *G. mirabilis*. From the description of *G. subiculosus* (Grevillea **16**: 97. 1887) one would hardly refer the present plant there, as it is described as furfuraceous and wood colored on the outside, with spores 4μ thick, but the types at Kew from Trinity Bay, Australia, are essentially like our plants from Jamaica. There are two open plants and several more or less crushed buttons. The best specimen shows a spore sac about 7 mm. thick, dark brown; peristome not outlined by a groove or ridge but paler and fibrous. Surface of buttons minutely spongy, of older plants nearly glabrous. Largest button 1.1 cm. thick. Subiculum white, membranous. Spores spherical, practically smooth, some finely dotted, 3-3.8μ.

Lycoperdon pusio B. & C. is apparently a *Geaster*. The co-types in the Curtis Herbarium, No. 253 (Cuba) are all buttons, but they look just like another collection so labelled, also from Cuba (Wright), in which the plants are open. These last are small Geasters looking very much like *G. subiculosus*, with pale, smooth surface, and conspicuous mycelium. The spores, however, are not those of any member of this group, but are 3.8-4.8μ thick, with distinct, blunt warts.

Illustrations: Lloyd. As cited above.

Jamaica. Hope. Earle, coll. (N. Y. Bot. Gard. Herb., No. 184).

Geaster mammosus Fr.

G. corallinus (Batsch) Hollos.

G. lugubris Kalch.

G. argenteus Cooke.

PLATES 35 AND 36

Button bulb-shaped with a distinct tapering point about 3-4 mm. long when dry, covered all over with a finely felted, thin, soft, buffy yellow coat which is usually quite clean of dirt except at the base and apparently exposed. Mycelium basal; outer scurf wearing off gradually and exposing the glabrous shining copper brown or darker, fibrous layer of the rays, which are about 8-12 in number, of unequal width and strongly hygroscopic; fleshy layer thick, adnate, smooth, at first gray-brown then darker brown to blackish. Inner peridium 5-15 mm. thick, subglobose to compressed, very finely puberulent, sessile, grayish to brown then darker; peristome distinctly outlined by a depressed border, plane, silky-strigose, the mouth elevated and papillose-fimbriated. Expanded plants up to 5.5 cm. broad.

Spores (of a Canada plant) spherical, minutely warted, 3-3.7μ.

Easily defined in the hygroscopic section by the clearly outlined silky-fibrous, plane and non-sulcate peristome. The above description was mostly drawn from a fine collection from Canada, containing one button and plants of various ages and sizes (N. Y. Bot. Gard. Herb., no data except Canada).

Plants in the Lloyd Herbarium from Paris (L. Rolland) are like American specimens, with a spongy, yellow, nearly clean superficial layer peeling off in flakes; the mouth distinct. Plants in the same herbarium from Tucuman, Argentina, (Leon Castillon, coll.) are like the United States and European plants except that the outer layer when present is covered with sandy earth.

Geaster argenteus Cooke (Grevillea **17**: 75. 1889) is represented at Kew by three sets on the same sheet, all from Fort Carlton, Saskatchewan (one lot not named). The plants of the upper lot with pasted label giving fullest data we take as the types. The plants have the appearance of *G. mammosus* with outer superficial layer weathered off, showing the whitish, fibrous layer and blackish fleshy layer; spore sac sessile and largely enclosed by the strongly hygroscopic lobes. The mouth area is obvious as a silky zone, the center

more or less elevated and lacerate. The spores, which are spherical, distinctly warted, 3.7-4.5μ (pl. 36, fig. 13) are distinctly those of *mammosus* and not of *floriformis*, which are larger (5-7μ). Hollos considers *G. argenteus* the same as *G. floriformis*, but he apparently had not seen authentic specimens.

Geaster argentatus Cooke and Massee from Brisbane, Australia, is closely related. A part of the type collection is at the New York Botanical Garden. It has a definite silky peristome; spread of rays 3 cm., the outer surface scurfy and ochraceous at first, then smooth and gray to buffy gray; fleshy layer reddish brown; spore sac 12 mm. thick, finely furfuraceous to sub-granular, gray-brown to reddish brown, sessile. Spores dark, mostly spherical but some irregular, 4.5-6μ (pl. 36, fig. 17). Other plants from Kew Herbarium labelled *G. argentatus* Cooke from Victoria, Australia (not types), now pasted on the same sheet with *G. argenteus*, are quite different from the types, and we take them to be *G. Drummondii*, which they resemble in all important respects; mouth sulcate, spore sac granular to subasperate.

Illustrations: Destrée. l.c., pl. 9, fig. B.
De Toni. l.c., pl. 2, fig. O (as *G. lugubris*).
Hollos. l.c., pl. 10, figs. 1-3 (as *G. corallinus*).
Kalchbrenner. Gasteromycetes novi vel minus cogniti, pl. 5, fig. 3 (as *G. lugubris*). 1884.
Lloyd. The Geastrae, figs. 16, 17. Also pl. 98, figs. 7-11.
Micheli. Nov. Pl. Gen., pl. 100, fig. 3.
Smith. Grevillea 2: pl. 19, fig. 1. (Reproduced from Gardener's Chronicle).
Vittadini. Monog. Lycoperd., pl. 1, fig. 9.

North Carolina. Flat Rock. Memminger, coll. (Lloyd Herb., as *G. floriformis*).

New Jersey. Ellis, coll. (Lloyd Herb.).

Ohio. Cincinnati. Lloyd, coll. (Lloyd Herb.).

Wyoming. Cody. Davis, coll. (Lloyd Herb.).

Iowa. Iowa City. Teeters, coll. (Lloyd Herb.).

Colorado. Clements, coll. (Path. and Myc. Herb.); also Demetrio, coll. (N. Y. Bot. Gard. Herb.).

North Dakota. Fargo. Brenckle, coll. (Path. and Myc. Herb., Lloyd Herb., and U. N. C. Herb.). Note in Lloyd Herb. says "epigean." The plants show pointed buttons with yellow, spongy surface and some adhering humus; mouth distinct. Spores (of No. 254) minutely warted, 3.6-4.4μ.

Canada. (New York Bot. Gard. as *G. umbilicatus*).
London. Dearness, coll. (Lloyd Herb., and U. N. C. Herb.).
Nova Scotia Halifax. Crossland, coll. (Lloyd Herb.).

Geaster arenarius Lloyd

PLATES 24, 35, AND 36

Lloyd describes *G. arenarius* (The Geastrae, p. 28) as follows: "Exoperidium subhygroscopic, cut to five to ten segments; drying usually with segments incurved. Mycelial layer closely adnate with adhering sand. Fleshy layer closely adnate, light color, not rimose. Inner peridium subglobose, with a very short but distinct pedicel in some specimens, in others appearing sessile. Mouth even, conical, acute, definite and usually darker colored than the remainder of inner peridium. Columella indistinct. Spores globose, rough, 3-4μ."

The abundant type collection from Jupiter, Fla., (Culbertson, coll.) shows this to be a remarkable plant intermediate between *G. coronatus* and *G. floriformis*. In some the rays are distinctly revolute with the center elevated, in others the rays are closed in over or entirely under the sac. Though some of the rays are pliable they are distinctly hygroscopic, expanding quickly in water. Spore sac very faintly felted to glabrous, not at all granular-dotted as in *G. coronatus*, about 1 cm. thick, practically sessile; peristome varying from sharply outlined by a groove (about as in *G. coronatus*) to a less emphasized boundary as in *G. mammosus;* mouth apparently brown in the fresh condition, washing out pale and becoming lacerate. The outer layer of sand is thin and the flocculence holding it is very delicate and obscure. Spores minutely and irregularly warted, 3.2-3.8μ thick. Mixed with the types is a good specimen of *G. coronatus*, and this is almost certainly the plant referred to by Lloyd in his footnote as being an exception.

From the appearance of the rays of *G. arenarius*, which are acute, but not acuminate, the button is probably little if at all pointed. At the New York Botanical Garden there are two plants from Florida labelled *G. fimbriatus* (Underwood, coll., No. 1801a) that are almost certainly this species, though the mouth is only vaguely if at all determinate. The plants are small, hygroscopic, covered with sand on the outside; peristome vague, spore sac nearly glabrous; spores minutely warted, 3.7-4.5μ thick, just like those of Lloyd's plant and smaller than in *G. floriformis*.

The species is very near *G. floriformis* (see Lloyd, Myc. Notes, p. 143) and this approach is further emphasized by the vague peristome of the Underwood plants, which have the same spores as Lloyd's plants. The rays of *G. arenarius* are distinctly less rigid than in *G. floriformis*, but the smaller spores of the former are now the principal character separating the two species.

The extreme variation of Geasters is well shown by what appears to be a giant form of *G. arenarius* that is represented in the New York Botanical Garden by two very large plants from Greencastle, Indiana (as *G. rufescens*). They are 3.5-4 cm. thick with the rays closed over the spore sac. The peristome is vague, but the spores are like those of *G. arenarius*, minutely warted, 3.5-4μ thick, much smaller than in any other related species. Another interesting case is that of plants from Lake Titicaca, noted under *G. floriformis*.

Illustrations: Hollos. l.c., pl. 29, figs. 19, 20.
Lloyd. The Geastrae, figs. 53 and 54.

Florida. Lloyd. (U. N. C. Herb.). Another collection by Underwood. (N. Y. Bot. Gard. Herb., as *G. fimbriatus*).
Lake Helen. Mrs. Noble, coll. (Lloyd Herb.). Mouth distinct.
Grasmere. Baker, coll. (Lloyd Herb.).

Texas. Denton. Long, coll. (Lloyd Herb.). Mouth distinct. This is variable in its hygroscopic character.

Geaster rufescens Pers.

PLATES 25 AND 35

Plants large, the button subspherical, not pointed, entirely buried until dehiscence, when open 5 to 8 cm. wide; the thin outer mycelial membrane covered with earth or trash and tending to split away in patches from the fibrous layer which is flesh colored when fresh; rays splitting about half way to the base into about 7-9 lobes, or only shallowly into many more, the lobes when fresh are expanded or recurved, when dry recurved or the tips incurved, the unsplit basal portion convex above (vaulted beneath) as in the fornicate group. Fleshy layer of outer peridium very thick when fresh, up to 5 mm.; when dry forming a thinner crust with a felted-looking, brown surface on the face of the fibrous layer. Spore sac up to 4 cm. thick, depressed-globose, the base usually constricted into a short

PLATE 25

GEASTER RUFESCENS. No. 985.

thick stalk, not rarely with a low apophysis around the lower side of the spore sac some distance from the stem; color when fresh varying from pale flesh color to grayish flesh or deep brownish gray, when dry brown to gray brown, the surface not glabrous but covered with very minute, inherent scurfy dots (granular-velvety). Mouth slightly elevated, fibrous and becoming fimbriated, without a definite peristome (indeterminate). Columella large and subglobose, up to 1.5 cm. thick, the basal part with a peripheral extension as far as the apophysis.

Spores (of No. 985) globose, deep brown when mature, 3-4.4μ thick, minutely warted or asperulate, with a halo. Capillitium of simple threads which are about 3.5-4.8μ thick.

This fine species which is not at all rare in America grows usually around the bases of oak stumps and occurs in groups. One of the most remarkable characters is the very pleasant and decided fruity fragrance of the unopened and just opened plants. There has been considerable confusion regarding this plant and *G. limbatus*. As understood in Northern Europe (Fries, Berkeley, Massee), the latter differs in the expanded, not reversed rays, the darker and smoother inner peridium, the thinner and less spongy fleshy layer, and the more obvious peristome. For *G. limbatus* in the sense of Bresadola, in which sense we are using the name, see under that species. European specimens of *G. rufescens* are rare in American herbaria. One from Bresadola in the Lloyd Herbarium is like our plants, with spores 3.6-4.2μ thick, minutely warted. For comparison with *G. triplex* see that species.

Illustrations: Bulliard. Herb. Fr., pl. 471, fig. L.
De Toni. l.c., pl. 62, fig. I.
Hollos. l.c., pl. 11, figs. 7, 8.
Lloyd. The Geastrae, figs. 38-41. Also pl. 97, figs. 6-8.
Morgan. North Amer. Geasters, fig. 11. 1884.
Petri. l.c., figs. 45, 46.
Rea. l.c., pl. 19.
Smith. l.c., pl. 19, fig. 2.

683. Old Chapel Hill collection. No other data.

985. At base of an old oak stump, November 17, 1913.

1033. By path in woods, December 4, 1913.

2984. On old oak stump, December 4, 1917. Spores 3-4.4μ thick, apparently pitted in water, but upon application of KOH the surface appears spiny and with a halo.

6025. In earth at base of rotten oak stump.

6053. On deciduous leaf mold, January 28, 1923.

6066. Around a stump in Pritchard's pasture, February 12, 1923.

7221. On damp clay soil, November 25, 1923. A small form; the spore sac only 1 cm. thick. Spores 3.3-4μ.

Carolina. (Schw. Herb.; also in Michener Herb. from Schw. Herb.).

Alabama. Auburn. Under a rotting log, August, 1897. Baker, coll. (N. Y. Bot. Gard. Herb., as *G. limbatus*). Two folders, each with three buttons, which are up to 3 cm. broad, subspherical to compressed and completely covered with rotten wood held on by flocculence. Also a collection from Alabama by Peters. (Curtis Herb., as *G. limbatus*). This is typical *G. rufescens* with a short stalk; outer surface covered with earth held on by flocculence.

New York. Botanical Garden. Williams, coll. (N. Y. Bot. Gard. Herb.).

Ohio. Dayton. Foeerste, coll. Ellis, N. Am. Fungi, No. 1309, as *G. limbatus*. (N. Y. Bot. Gard. Herb. and Path and Myc. Herb.).
Norwood. Lloyd, coll. (Lloyd Herb.).
Chillicothe. Hard, coll. (Lloyd Herb.).
Preston. Morhan, coll. (Lloyd Herb., labelled *G. limbatus* by Morgan).

Missouri. Saint Louis. Hedgecock, coll. (Lloyd Herb.).

Wisconsin. Milwaukee. Brown, coll. (Lloyd Herb.). Buttons.
Cedarburg. Panly, coll. (Lloyd Herb.).

Ontario. Regina. Willing, coll. (Lloyd Herb.).

Japan. Sapporo. Miyabe, coll. (Lloyd Herb.).

Geaster Hieronymi Hennings

PLATE 35

Buttons embedded in the substratum, apparently slightly pointed; outer surface covered at first with sandy earth or trash which may later strip off in part as a layer. Rays expanded or the tips incurved, center concave below, pliable, about 5-8 in number; fleshy layer adnate, thin and brown. Spore sac 1.5-2 cm. broad, subsessile or with a short stalk, dark brown, harshly asperate with short, setose hairs. Peristome rather indefinite (not sulcate), silky, mouth fimbriate.

Spores (of plant from Jalapa, Mexico,) small and minutely warted, 2.6-3.6μ thick, often seeming slightly angular.

Except for the asperate spore sac the plant is very like *G. rufescens* or *G. fimbriatus* and seems certainly to belong to their group.

We have seen the type collection of *G. Hieronymi* in the Lloyd Herbarium, and find that it agrees closely with the Mexican plants.

There are also two other lots in the Lloyd Herbarium labelled *G. Hieronymi* from Brazil (Rick, coll.). One of these is as described above and like the type; the other is something different, with a sulcate mouth.

Illustration: Lloyd. Myc. Works, pl. 229, fig. 2347.

Mexico. Jalapa. Moist forest, alt. 5000 ft., Dec. 1909. Murrill, No. 244. (N. Y. Bot. Gard. Herb.)

Brazil. Rick, coll. (Lloyd Herb.).

Argentine. Hieronymus, coll. (Lloyd Herb.; type).

South Africa. Miss Duthie, coll. (Lloyd Herb.).

Geaster fornicatus (Huds.) Fr.

PLATES 26 AND 35

Plants of medium to large size, the outer peridium splitting beyond the middle into four (usually) to five (rarely more) lobes which bend strongly backward and downward, the tips remaining attached to an equal number of shorter lobes on the margin of a membranous cup, sunken in the earth and trash, which, as the outer layer of the button, was stripped off from the middle layer when evagination occurred. This cup is always completely covered with adhering trash and earth due to the flocculent mycelium wefting it. Rays firm, the fleshy layer dark brown and adherent or partly peeled off, in old plants worn away; the exposed fibrous layer whitish tan. Inner peridium seated on a distinct, whitish, short stalk about 2-3 mm. long (in our plants), subglobose or urn-shaped to depressed, constricted near the base so as to form a ring; surface dark brown, finely velvety; mouth large, slightly elevated, fibrous lacerated, wrinkled, without a distinct peristome, but the paler brown fibers in older plants have a distinct limit exactly as in *G. limbatus* (sense of Hollos), which is very near. Columella not large, about 3 or 4 mm. high and 2.5 mm. broad (in the Smith's Island plant).

Spores spherical, blackish brown, distinctly warted under high power with rather regular, blunt warts, 3.7-4.5μ thick. Capillitium threads 3-7.5μ thick, about as dark as the spores; walls roughened.

This is a rare plant in the United States and is reported by Lloyd only from Texas and Catalina Island. In the rest of the world it is supposed to be of wide but erratic distribution (Lloyd, Lycoper-

daceae of Australia, etc., p. 21). The report by Curtis that it is common in this state almost certainly refers to what we now call *G. coronatus* ,Catl. Plants of North Carolina, p. 110), as all the plants in his herbarium under *G. fornicatus* are the latter species. Our single collection from this state consists of three plants in fine condition that grew under cedar, but the species is reported as growing under both conifers and frondose plants. It is easily distinguished from *G. coronatus* by the absence of an outlined peristome and the entirely different surface of the inner peridium. The species is really most nearly related to *G. rufescens* which is very similar in fundamental characters, as mouth, surface of inner peridium, separating layers of the outer peridium, and concave base when expanded. The spores, too, are very similar. The two species, however, are not forms of the same thing, but are easily distinguished by the fornicate habit, fewer and more rigid lobes, and darker and more densely velvety inner peridium of *G. fornicatus*. For supposed synonyms see Hollos, p. 154.

Illustrations: Batsch. Elench. Fung., pl. 29, fig. 168.
Corda. Icon. Fung. 5: pl. 4, fig. 43.
Destrée. l.c., pl. 6, fig. B.
Hollos. l.c., pl. 8, figs. 9-18; pl. 29, fig. 26.
Krombholz. Abbild., pl. 6, fig. 11.
Lloyd. Myc. Works, pl. 96, figs. 1-3 (fig. 2 was first published as *G. fenestratus* in Myc. Notes, p. 70, fig. 33).
Massee. Ann. Bot. 4: pl. 2, fig. 42.
Massee. Brit. Fung. and Lichens, pl. 35, fig. 5.
Petri. l.c., fig. 44, 2.
Rea. l.c., pl. 17.
Smith. l.c., pl. 15, fig. 2.
Sowerby. Eng. Fung. 2: pl. 198.

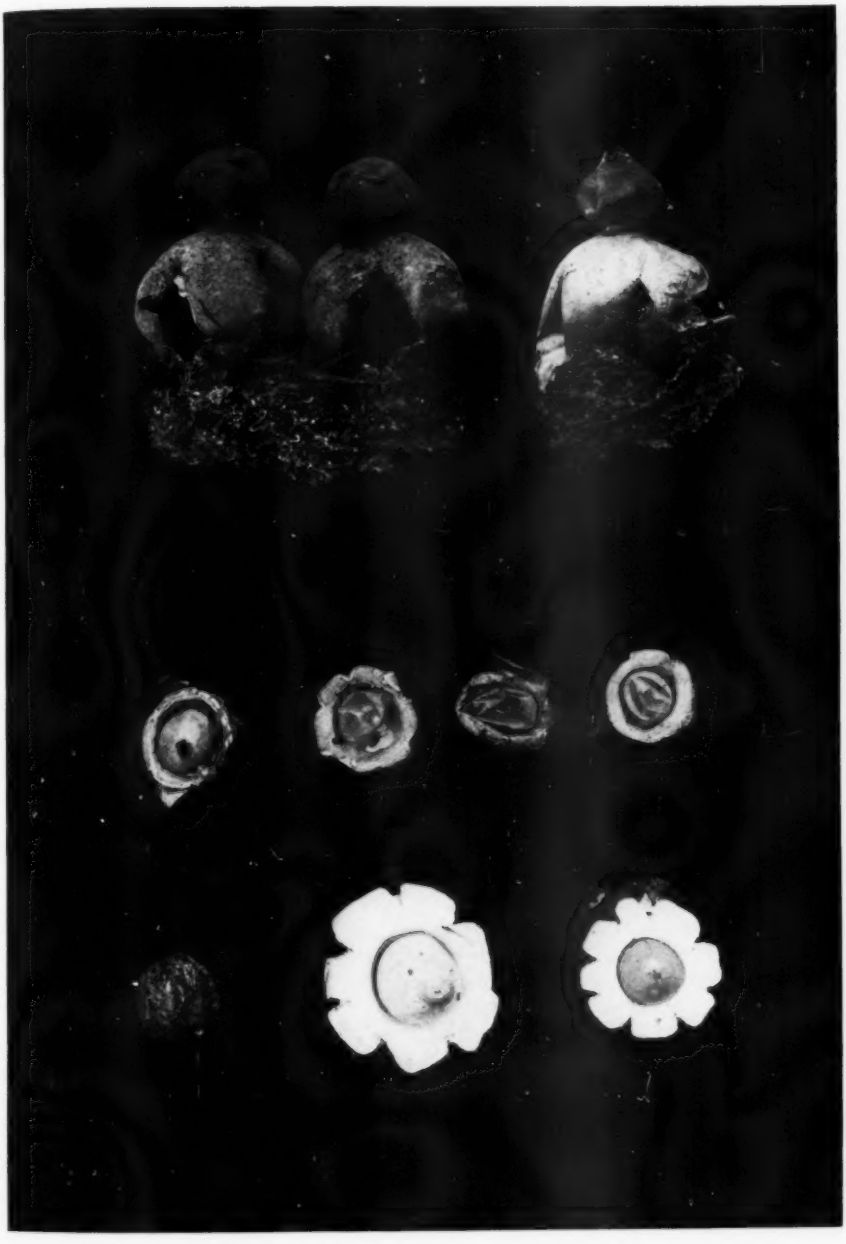
Smith's Island. In a dense bed of cedar twigs under a cedar in sandy soil, December 29, 1921. Couch and Grant, colls.

Geaster fimbriatus Fr.
G. tunicatus Vitt.

PLATES 26, 27, AND 35

Plants small, in our collections up to 3 cm. wide when freshly expanded; inner peridium about 9-14 mm. thick when fresh, subspherical, pale or dark brown, sessile in and surrounded by the concave lower half of the outer peridium; mouth on a more or less elevated

PLATE 26



[Above] GEASTER FORNICATUS. Smith's Island.
[Below] GEASTER FIMBRIATUS. No. 7093 [upper 4 dry plants].
No. 7097 [lower 3 fresh plants].

concolorous or paler cone, but without a definitely outlined area around it, the margin fibrous-flocculent and at times lacerate, not sulcate. Outer peridium splitting about half way down into 5-8 lobes which when freshly expanded are strongly recurved around the margin of the bowl-shaped base, usually remaining recurved in the dry state, not hygroscopic. Mycelial layer very thin with wefted surface, pale tan or buff to soaked ochraceous when fresh, tending to peel away in part from the rays but as a rule not nearly so much so as in *G. velutinus*. Fleshy layer pallid (nearly white) and about 2 mm. thick when fresh, drying down to an extremely thin, smooth or finely cracked up, brown or ochraceous membrane or scurf which disappears only after much exposure. Buttons quite spherical, not pointed, completely covered by humus and trash and retaining trash over the whole or most of the surface after opening. Columella in the mature plant represented by a small, subspherical, pale core some distance from the base.

Spores (of No. 7093) dark smoky brown, spherical, very minutely asperulate, many appearing smooth except under high power, 2.2-3.4μ, most about 3μ. Capillitium threads unbranched, about 5μ thick, sometimes up to 7μ usually lighter than the spores, but varying in color in plants of the same colony.

This small *Geaster* grows usually in groups of several, not truly cespitose (rarely crowded in twos or threes), in partly rotten leaves and trash under cedars or in mixed woods. As is to be expected, specimens are found (rarely) that are not saccate but have the outer peridium concave below. It also happens occasionally that the outer layer may peel off completely. For both of these variations see plants from Lynn, England (Plowright, coll.) at the New York Botanical Garden.

In American herbaria this is often referred to *G. saccatus*. Lloyd thinks that *G. fimbriatus* does not occur in America (The Geastrae, p. 37), though reported by Morgan and others. However, as our plants agree clearly with this species in all important points (indeterminate mouth, splitting of the outer peridium into two layers in part, etc.), we see no reason not to refer them to it. In cases where the paleness of the mouth area is most pronounced as in plants from Buck Hill Falls, Pa., (see below) some authors might be inclined to call it definite, but there is no structural boundary and except for color the mouth is exactly as in other forms. The European plant also

has a tendency to a paler mouth area. As Lloyd says, the mouth is no more fimbriate than in some other species. The true European *G. fimbriatus* is represented by plants in Washington (Path. & Myc. Herb.) from lower Austria collected by Zahlbrückner and determined by Keissler. They are just like our plants. We have received from Patouillard another typical European specimen (Jura) with spores minutely warted, 2.5-3.5μ thick. Still a third (N. Y. Bot. Gard. Herb. from Herb. of Thümen) has spores a trifle larger (3.4-4μ) but is otherwise identical. It grew in coniferous woods and still shows fir leaves attached.

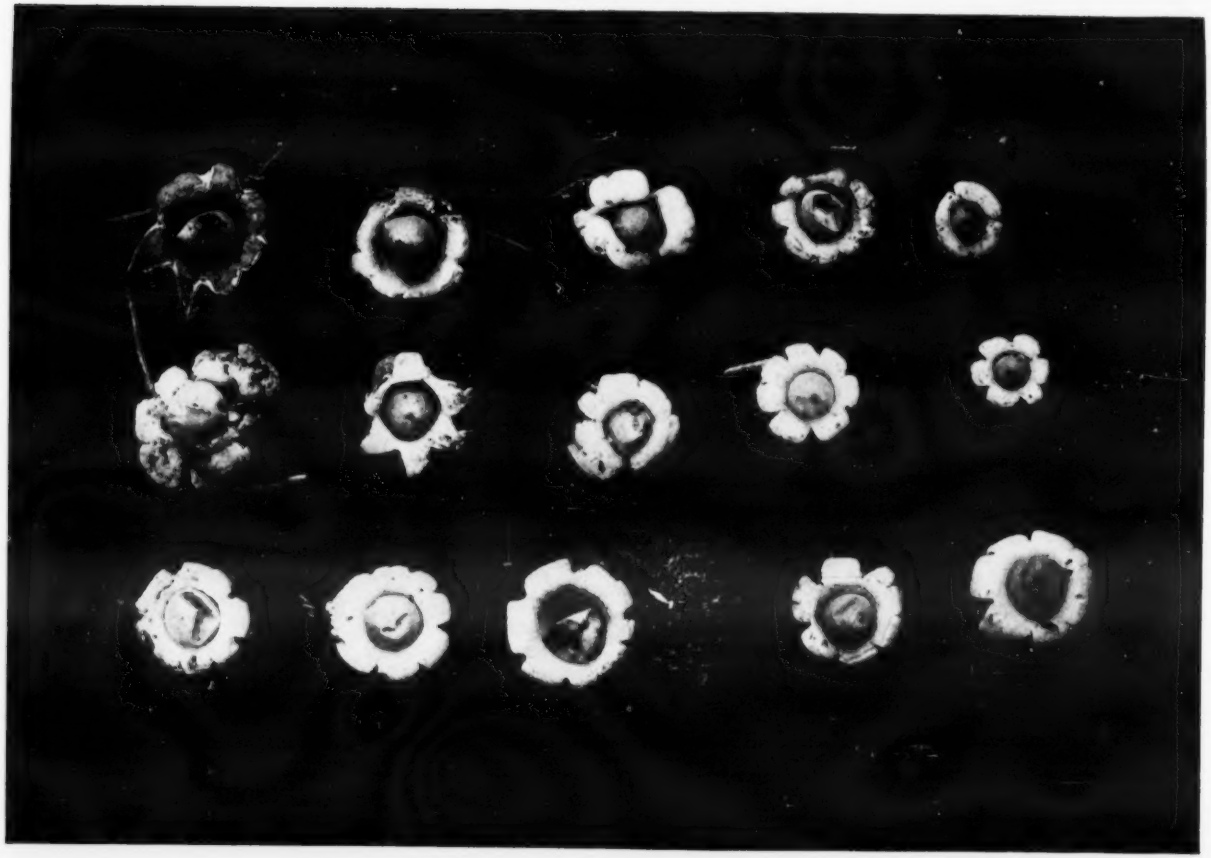
A European collection from Sydow (Flora Marchica, Charlottenburger Schlossgarten, P. Sydow, coll.) labelled *G. fimbriatus* and now at the New York Botanical Garden is not the plant we here describe, but *G. lageniformis* with much rougher spores and determinate mouth. Our plants agree with Rea's description of *G. fimbriatus* except in size of spores which he gives as 4-5μ. It is very likely that *G. triplex* (with *G. lageniformis*) and *G. fimbriatus* have been often confused.

Geaster rufescens is the nearest relative of *G. fimbriatus*, and large plants of the latter might easily be referred to it. The thinner fleshy layer, more saccate form, and smaller average size distinguish *G. fimbriatus*, but there may be connecting forms. *Geaster tunicatus* as represented in Saccardo, Mycotheca italica, No. 1625 (Mendola; Bresadola, coll.) is *G. fimbriatus*. The mouth is indefinite, the base saccate. The two species are also treated as synonyms by Hollos.

Illustrations: Berkeley. Outlines Brit. Fung., pl. 20, fig. 4.
Destrée. l.c., pl. 10, fig. A.
De Toni. l.c., pl. 63, fig. P.
Hollos. l.c., pl. 10, figs. 17 and 18.
Lloyd. The Geastrae, fig. 74.
Michael. Führer f. Pilzfreunde 2: No. 202, figs. a and b. 1913 (2nd. ed).
Morgan. North American Geasters, fig. 8.
Petri. l.c., fig. 42.
Rea. l.c., pl. 19.
Schmidel. Icon. Plant., pl. 50, figs. 1-4. 1747.
Smith. Grevillea 2: pl. 17, fig. 2.
Sowerby. Engl. Fungi, pl. 80.

1291. In cedar twigs and oak leaves mixed at the base of a cedar tree, September 30, 1914. Spores minutely asperulate, up to 3.7μ thick.

PLATE 27



GEASTER FIMBRIATUS. No. 7135.

4096. In leaves (mostly foliose), mixed woods, summer of 1919. Spores as usual, 2.5-3.8μ thick. Capillitium threads unbranched, up to 7μ thick, most about 4.8μ, much paler than the spores.

7092. Under cedar tree, August 24, 1923. Spores 2.8-3.7μ. Capillitium threads thick-walled, nearly hyaline, up to 6.6μ thick.

7093. In rotting frondose leaves, August 24, 1923. Spores dark under the microscope, surface as usual, 2.2-3.4μ thick.

7097. Completely covered by decaying cedar twigs (same spot as No. 7092), August 27, 1923. Two open plants and a button. Spores 2.6-3.7μ. Capillitium threads straight, not sinuous, concolorous or slightly lighter than the spores.

7135. Under cedars, September 22, 1923. Mouth not defined. Mycelium universal.

Statesville. Beardslee, coll. (Lloyd Herb., as *G. saccatus*).

South Carolina. Society Hill. (Curtis Herb., as *G. fimbriatus*, No. 3833).

Tennessee. Unaka Springs. Murrill, coll. (N. Y. Bot. Gard. Herb.).

Pennsylvania. New Garden. (Michener Herb., as *G. minimus*).

New Hampshire. Shelburne. Farlow, coll. (Farlow Herb.).

Wisconsin. Eagle Heights, near Madison, August 26, 1903. No distinct peristome. Spores very faintly spiny, 3-3.7μ thick. (U. N. C. Herb.).

Ohio. Miami Valley. Morgan, coll. (N. Y. Bot. Gard. Herb.).

Colorado. Minnehaha. Clements, Crypt. Form. Colo., No. 194, as *G. limbatus* (in part). (Farlow Herb.).

Denver. Bethel, coll. (N. Y. Bot. Gard. Herb.).

Ontario. Sarina. Bertolet, coll. (Lloyd Herb., as *G. saccatus*). Also collection from Canada by Dearness. (U. N. C. Herb.).

Geaster floriformis Vitt.

G. delicatus Morg.

PLATES 24, 35, AND 36

Plants (typically) small, with a spread when expanded of 2-2.5 cm., submerged until mature; rays about 8-10, unequal, hygroscopic and expanding quickly when put into water, covered at first with sandy earth held on by mycelium, this flaking off by degrees to leave the surface smooth and pale after exposure; fleshy layer dark brown, adnate, continuous then rimose; inner peridium about 6-8 mm. thick, subglobose or depressed, sessile, pale, covered at first with fine granules or furfuraceous particles which soon wear away in large part; mouth only a puncture or slit with short radiating fissures with no defined or silky area around it as a rule, after a time the margin becoming fimbriate.

Spores (of Clements, No. 613) distinctly warted, spherical, 5-7μ thick, or slightly elongated and about 6.5 x 7.4μ. Capillitium threads straight, thick-walled, up to 7μ thick.

The American plants are like those of a good collection from Hollos (Hungary) sent us through the kindness of Patouillard. In these plants the peristome is indefinite, rays strongly hygroscopic, spores spherical or somewhat irregular, distinctly warted, 5-7 x 6-8μ. Similar plants from Hollos have been seen by us in the Lloyd Herbarium.

Good collections of this species from San Diego, California, in Washington and New York show an interesting variation in the mouth. In the plants at the New York Botanical Garden the two plants with mouths visible show a depressed zone around the mouth but the surface of the zone is not silky as in most Geasters, but of the same texture as the remainder of the surface. In one of the plants the mouth was an elevated papilla in the center of this zone; in the other it was a plane opening. For a similar variation see plants from Florida and North Dakota entered below. The plants in Washington show a plane opening without a depressed zone. In most herbarium material the spore sac is nearly smooth or faintly powdery. The granules when present are not so large as in *G. asper*. The rays when dry are either folded over the top of the inner peridium or are curved in more abruptly with their tips under it, or they may take any intermediate position. The species grows in sandy soil and in this country is apparently confined to the western states, occurring also in Europe and Africa. A large form of this with the spore sac 2 cm. thick (in the pressed condition) is represented in the Herbarium of the Museum of Paris from western Africa. Except in size they do not differ apparently from the American plants. The spores are distinctly warted, 5-6.5 x 6-7μ. An interesting plant that seems referable to this as a variant is represented in the Farlow Herbarium from Lake Titicaca, Bolivia (Mrs. Shepard, coll.). The rays are thick, strongly hygroscopic, covered with sand; spore sac densely furfuraceous, nearly white, peristome vaguely defined by a low ridge, fimbriate; spores spherical to irregular, distinctly warted, 4-5μ thick or up to 6μ long.

In his treatment of *G. delicatus* (The Geastrae, p. 11), Lloyd makes the mistake of referring to *G. lageniformis* when he should have said *G. floriformis* (see Hollos, p. 67).

Illustration: De Toni. l.c., pl. 1, fig. O.
Hollos. l.c., pl. 10, figs. 20-25; pl. 29, figs. 29, 30.
Lloyd. The Geastrae, figs. 14, 15 (as *G. delicatus*) and fig. 78; also pl. 98, figs. 12-18.
Morgan. The Genus Geaster, fig. 2 (as *G. delicatus*).
Petri. l.c., fig. 43.
Vittadini. Monog. Lycoperd., pl. 1, fig. 5. 1842.

Florida. Grasmere. Baker, coll. (Lloyd Herb.). Mouth indistinct. Two other boxes of same show very minute plants, many not over 4-5 mm. in diameter when closed; many with depressed mouth area.

Texas. Denton. Long, coll. (Lloyd Herb.). Columella cylindrical, about 4 mm. long.

California. San Diego. Orcutt, coll. (Path. and Myc. Herb. and N. Y. Bot. Gard. Herb., as *G. delicatus*). Spores subspherical, about 5-6.8μ thick.
Catalina Island. Mrs. Trask, coll. (Lloyd Herb.).

South California, 32-36° N. Lat. Parry, coll. (Curtis Herb., as *G. rufescens*).

Colorado. Yuma. Clements, No. 613. (N. Y. Bot. Gard. Herb.). Spore sacs distinctly granular.

North Dakota. Brenckle, coll. (Path. and Myc. Herb. and U. N. C. Herb., No. 152 of Sydow, Fungi. Exot. Exs.). Spores spherical or somewhat elongated, 4.2-5 x 5-7μ. In Lloyd's Herbarium plants from N. Dakota (Brenckle, coll.) show a more or less definite, depressed area around the mouth.

Nebraska. Lincoln. Webber, coll. (N. Y. Bot. Gard. Herb.; also in Path. and Myc. Herb. as E. & E. N. Am. Fungi, No. 1941).

Washington. Cheney. Mrs. Tucker, coll. (Lloyd Herb.). Lloyd has a note saying, "Mrs. Tucker writes me that this species proves quite a pest in flower beds."

Canada. London. Dearness, coll. (U. N. C. Herb.).

Transvaal. Pretoria. Evans, coll. (Lloyd Herb.).

New Zealand. Rangitata. Barker, coll. (Lloyd Herb.).

Geaster coronatus (Schaeff.) Schroet.
G. minimus Schw. (not *Geastrum minimum* Chevallier).
G. marginatus Vitt.
G. quadrifidum Schw.
G. Cesatii Rabenhorst.

PLATES 28-30, 35, AND 36

Plants when expanded 1.5-3.5 cm. broad and up to 3.3 cm. tall excluding the basal cup when present; outer peridium splitting into 4-8 strongly recurved or rarely horizontal lobes, the mycelial layer often being stripped off and remaining as an obscure weft which

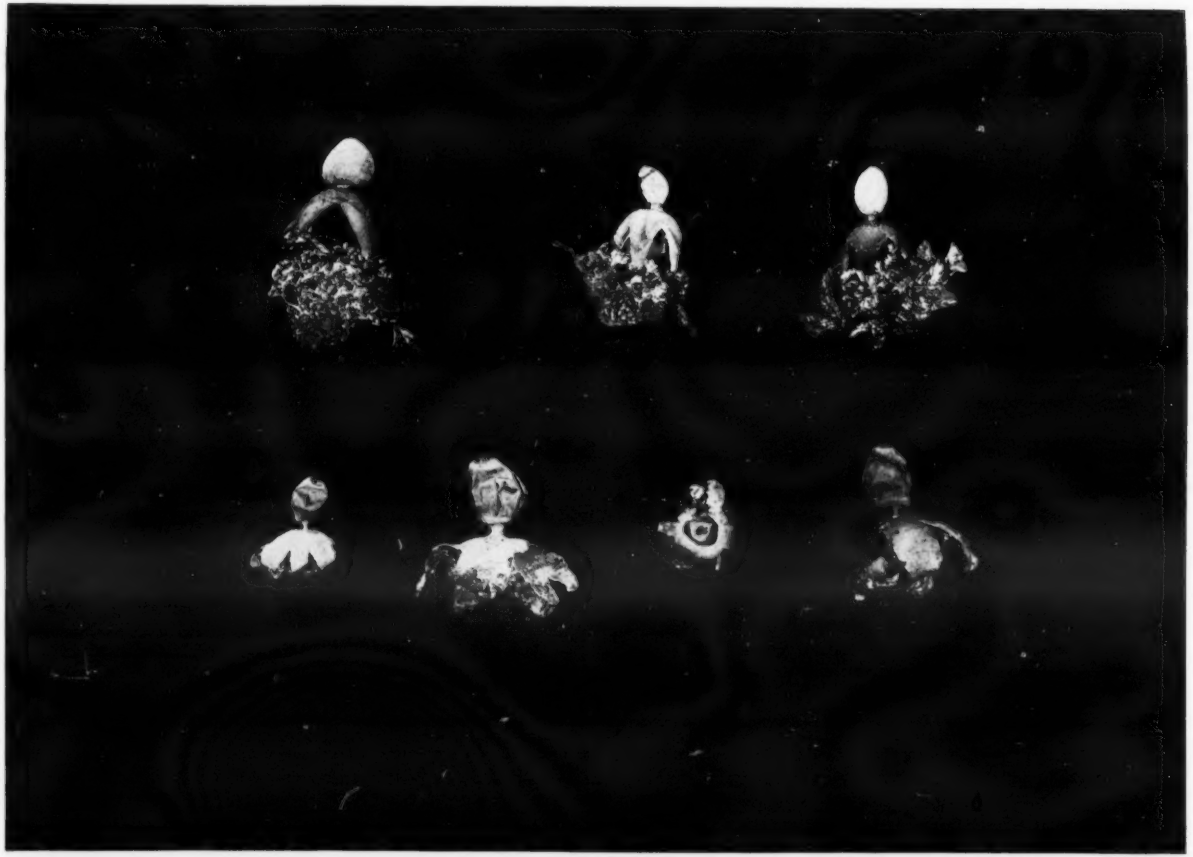
holds together a hollow mass of earth or trash out of which the plant was lifted, the tips of the rays attached to its margin (typical or fornicate form); in other cases the mycelial layer with the adhering trash is lifted with the plant and forms a more or less persistent coat on the outer surface (form *minimus*); fleshy layer brown, cracking and often seceding in large part from the rays, the central part most persistent and at times forming a low collar around the base of the stalk. Inner peridium ovoid to oblong, 4-14μ thick, brown to umber or slate color, the surface, except when weather-worn, powdered with minute glistening particles; stalk distinct, about 1.5-2.5 mm. long and expanding above into a ridge which in some specimens may have an acute rim like a little collar. Mouth delicately fimbriated, not sulcate, low, abruptly or gradually elevated from a nearly flat, sharply defined silky area which is outlined by a groove. Columella in mature plant not obvious.

Spores (of No. 3881) dark smoky purplish, distinctly rough, 4-5.1μ thick, most about 4.5μ. Capillitium threads up to 6μ thick, not sinuous and branching rarely if at all.

This species has been confused with *G. fornicatus* both in Europe and America and it is treated under the latter name by Morgan. We are following Lloyd and Hollos in using the name *G. coronatus* for the present species. The true *G. fornicatus*, as now understood, is usually larger and is easily distinguished by the absence of a well defined mouth area, the different surface of the spore sac, and by the smaller and less strongly warted spores.

The type of *G. minimus* in the Schweinitz Herbarium is just like the usual *G. minimus* of herbaria; the spores distinctly warted, 3.7-4.4μ thick. Another authentic specimen of *G. minimus* from Schweinitz, now in the Michener Herbarium in Washington, is just like the form that we are calling *G. minimus*. Lloyd has seen the plant in the Schweinitz Herbarium and says that it is the same as the *minimus* form. We find it impossible to distinguish between *G. coronatus* and *G. minimus*. If the mycelial layer with its trash remains attached and is lifted when the rays bend back we have the *minimus* form, if not it is the *coronatus* form, and both forms with intermediates may occur in the same colony. Smaller size does not distinguish *minimus*, as we have seen the fornicate form with the inner peridium less than 5 mm. thick.

PLATE 28



GEASTER CORONATUS. No. 75 [above]; No. 684 [below].

In several plants in our collections the ridge around the expanded top of the stem, which is often obvious in stalked species, is terminated by a distinct, fimbriated frill, recalling the broader frill of *G. Bryantii.* The last mentioned is distinguished by its sulcate and more narrow and elevated mouth, by the distinct columella and by the broader frill. Both forms of *G. coronatus* are widely distributed in the United States and are not uncommon. In Europe the *minimus* form seems much rarer. The European plant is represented in Torrend's Mycotheca Lusitanica No. 79 *(in pinetis)*, also in Cesati's Herbarium Mycol., No. 1634 (as *G. Cesatii.* Both in Path. and Myc. Herb., Washington). In *G. Cesatii* the spores are distinctly warted, 3.8-4.5μ thick.

Geaster granulosus is an extreme form or variety of *G. minimus* with distinctly larger granules on the spore sac and in some cases covering it almost solidly with a white crust, at least as much so as in *G. calceus* as shown by Lloyd's fig. 9, pl. 95. We have studied authentic specimens of *G. granulosus* from Austria (Fuckel, coll.) and find the spores to be larger and rougher than in *G. minimus*, 4.2-5.6μ thick, often with an angular appearance from the irregular warts (pl. 36, fig. 12). A plant from Ymala, Mexico, has the exact superficial appearance of *G. granulosus* and the spores approach those of that species, with the same irregularity, but are somewhat smaller, 3.8-5μ. They have the form of spores of *G. minimus* shown on pl. 35, fig. 24, and are only slightly larger. *Geaster calceus* Lloyd (Myc. Notes, p. 311) from South Africa is very near the last, but with smaller spores (3.5-4.2μ), of regular, spherical shape and with equal warts (pl. 36, fig. 11).

A peculiar plant is represented in the Path. and Myc. Herbarium by three specimens from Waste Land, South Dakota, (Wilcox, coll.). It looks like a small, nearly sessile specimen of *G. minimus* but the spores are distinctly larger and irregular (4.8-5.5 x 6.4-7.5μ), with large, unequal warts (pl. 36, fig. 16). The plant bears the ms. name of *G. terreus* Ellis, n. sp., with description in ms. attached. It may be a new species, but is more probably an extreme variant of the *minimus* type.

Noack (cited below) reports this fungus, which he calls *G. fornicatus*, as forming mycorhizas on the roots of conifers.

Illustrations: De Toni. l.c., pl. 63, fig. H and fig. I (as *G. marginatus*).
Hard. Mushrooms, fig. 482 (as *G. minimus*).
Hollos. l.c., pl. 7, figs. 11-14 (as *G. coronatus*); pl. 10, figs. 8-10; pl. 29, fig. 28 (as *G. minimus*).
Lloyd. The Geastrae, figs. 50-52 (as *G. minimus*); figs. 58-61 (as *G. coronatus*; fig. 59 was first published as *G. fornicatus*, Myc. Notes, p. 71, fig. 36). Also pl. 95, figs. 1-7 (as *G. minimus*).
Macbride. Mycologia **4**: pl. 62, fig. 2 (as *G. marginatus*) and fig. 3 (as *G. minimus*). 1912.
Morgan. North Amer. Geasters, fig. 1 (as *G. fornicatus*) and fig. 7 (as *G. minimus*).
Nees von Esenbeck. Syst. Pilze Schw., pl. 12, fig. 128 (as *Geastrum quadrifidum*). 1817.
Noack. Bot. Zeit. **47**: pl. 5, fig. 1 (as *G. fornicatus*). 1889.
Petri. l.c., fig. 37, No. 1 (as *G. minimus*); fig. 44, No. 4 (as *G. coronatus*).
Schmidel. Icon. Plant., pl. 37, figs. 1-3 (as *G. coronatus*). 1747.
Vittadini. Monog. Lycoperd., pl. 1, fig. 6 (as *G. marginatus*). 1843.

75. On mossy shaded ground under cedars, November 10, 1911. Fornicate form. Spores 3.7-4.4μ, most about 3.9μ thick. Capillitium threads sinuous, up to 5.5μ thick.

684. On ground under cedars, 1908. *Minimus* form. Spores minutely warted, 3.2-4.4μ, most about 3.7μ thick.

3881. By a decaying oak stump in Strowd's lowgrounds, December 13, 1919. Fornicate form and *minimus* form mixed in same colony.

5903. On a damp mossy bank in Battle's Park, October 25, 1922. Fornicate form. Spores indistinctly rough, 3.8-4.2μ, most about 3.7μ thick. Capillitium threads sinuous, up to 4μ thick.

6065. By a cedar stump in a pasture, February 12, 1923. Fornicate form. Spores distinctly warted, 4-5.3μ, most about 4.6μ thick. Capillitium threads straight, apparently unbranched, up to 5.1μ thick.

6076. On ground in a meadow, April 17, 1923. Fornicate form.

6077. On the ground near cemetery, April 17, 1923. Fornicate form. Spores variable in size, many imperfect ones, the normal ones 3.7-4.8μ thick, distinctly rough. Capillitium threads usually straight, up to 5μ thick.

6091. On the ground by a decaying oak stump, May 20, 1923. Fornicate form. Spores distinctly warted, 4-5.1μ thick. Capillitium threads straight, apparently unbranched, up to 7μ thick.

Raleigh. Wells, coll. (U. N. C. Herb.).

Smith's Island. Couch and Grant, coll. No. 5965. In sandy soil, December 29, 1921. *Minimus* form. Spores minutely warted, 4-5μ.

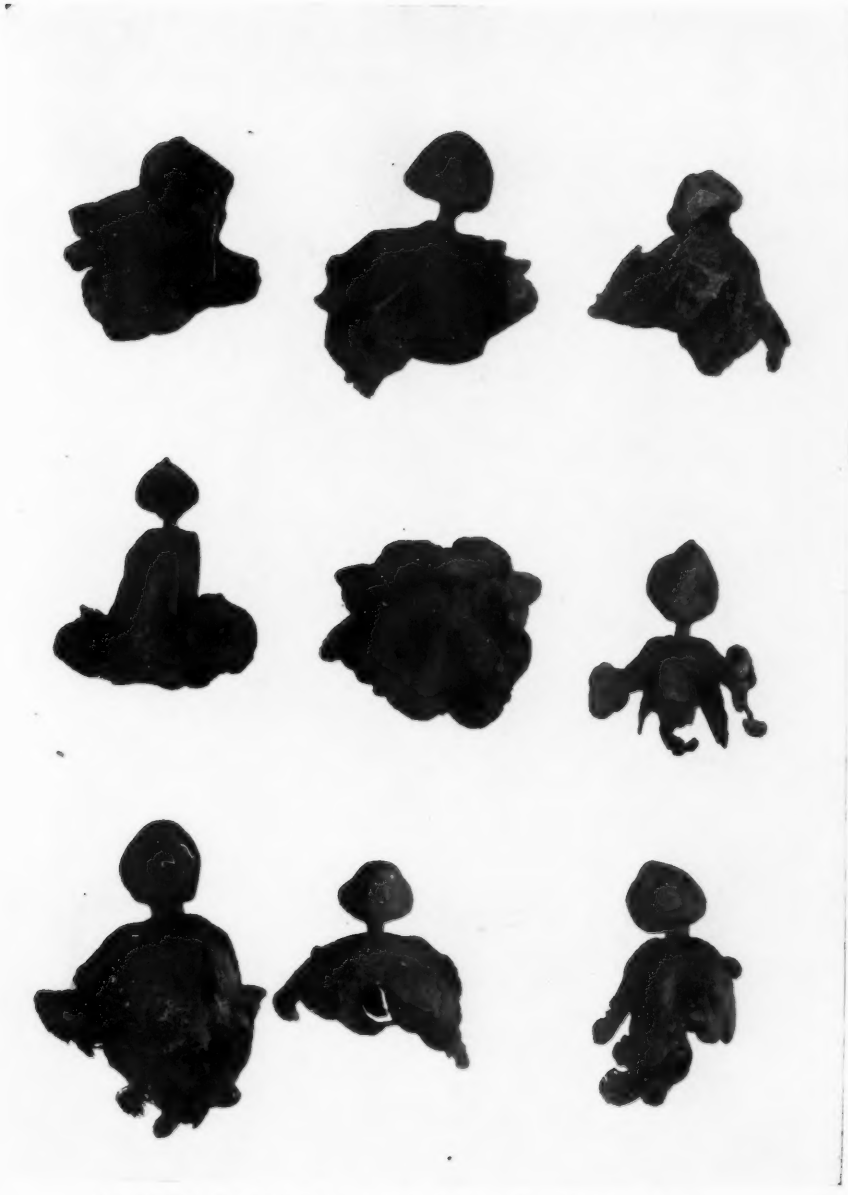
"Carolina." Pine woods. (Michener Herb. from Schw. Herb., as *G. fornicatus* and *G. striatus*). Also in Schw. Herb., No. 2247, as *G. quadrifidum*.

South Carolina. Aiken. Ravenel, coll. (Path. and Myc. Herb., as *G. minimus*, Fung. Am. Exs., No. 472). Also Fung. Car. Exs., No. 74. (Phila. Acad., as *G. minimus*).

PLATE 29

GEASTER CORONATUS. No. 3881. Fresh condition.

PLATE 30



GEASTER CORONATUS. No. 3881 [top row]; No. 5965 [others].

Society Hill. (Curtis Herb., as *G. fornicatus*, No. 2301).
Also a collection from South Carolina by Ravenel in Michener Herb., as *G. minimus*.

Florida. DeFuniak Springs. Fisher, coll. (Lloyd Herb.). These plants have a distinct apophysis with a distinct edge as in one or more of our Chapel Hill collections, but is not exactly typical *G. coronatus* as the sac particles are dull and look more like specks of dust.

New Jersey. In very sandy soil. Ellis, coll. (N. Y. Bot. Gard, Herb.). Lobes varying from 4-8; an imperfect cup attached in some, in others not.

New York. Mohawk. Mrs. Lobenstein. (N. Y. Bot. Gard. Herb., as *G. fornicatus*).

Massachusetts. Boston. Sprague, No. 42. (Curtis Herb., as *G. minimus*). There are also two typical specimens of *minimus* from Schweinitz Herb. in the Curtis Herb.

Ohio. Lloyd, coll. (N. Y. Bot. Gard. Herb., as *G. minimus*, and U. N. C. Herb.). Spores distinctly warted, 3.8-5.5μ thick. Capillitium threads straight, up to 5.5μ thick.

Michigan. Agricultural College. Wheeler, coll. (Path. and Myc. Herb., as *G. minimus*).

Wisconsin. (Univ. Wis. Herb., as *G. minimus*. and U. N. C. Herb.). Spores distinctly warted, 3.7-4.4μ thick.

Texas. Wright, No. 326. (Curtis Herb., as *G. fornicatus*).

California. Pasadena. McClatchie, coll. (N. Y. Bot. Gard. Herb.).

Canada. Macoun, coll. (N. Y. Bot. Gard. Herb., as *G. minimus*, and U. N. C. Herb.). Minute plants of both forms. Lobes varying from 4-8, revolute, the earth mass attached in some.

Jamaica. A. E. Wright, coll. (Farlow Herb., as *G. limbatus*). One is covered with coarse white particles like Lloyd's *G. calceus*.

Mexico. Ymala. (Path. and Myc. Herb.). *Minimus* form with large granules like *G. granulosus*. Spores 3.8-5μ.

Ecuador. Mille, coll. (Lloyd Herb.).

Japan. Sapporo. Miyabe, coll. (Lloyd Herb.).

Geaster leptospermus Atk. & Coker.

PLATES 31 AND 35

Inner peridium nearly globular, 2.5-5 (rarely 6.5) mm. thick, pale gray to pale tan in color, minutely dusted with fine whitish particles which also cover the inner surface of the freshly opened rays; mouth very small, minutely fibrous, surrounded by a conical, white disc which is distinctly outlined and radially fibrous (not sulcate).

Fibrous layer of the outer peridium splitting into 3-6 rays about half way down or more, the rays recurving and the base becoming arched up (vaulted beneath), leaving the delicate, fibrous, mycelial layer as a distinct, membranous, white cup beneath, with its margin also rayed by slits, the rays attached to the rays of the plant above (typically fornicate). Inner surface of the rays when freshly opened covered with a succulent, pale buff, fleshy layer, which when dry forms the thin, tan or light brown, smooth and nearly complete membrane over the fibrous layer; underside of the rays white and smooth. Columella not obvious.

Spores (of No. 2028) minute, spherical, 2-3μ, usually appearing under high power as if very minutely punctate or asperulate. Capillitium threads unbranched, about 3μ thick. Both spores and capillitium very pale yellow-brown (whitish).

This is a very distinct and well marked little species and is the smallest known *Geaster*, the inner peridium of a full-grown plant seldom reaching over 5 mm. in diameter. They have the unique habit of growing in moss on tree trunks, as cedar, hickory, elm, etc., and usually from about four feet from the ground up, most of our collection coming from a height of ten to twenty feet. It is not at all uncommon in Chapel Hill, which is the only known station, and is distinctly a cold weather species, appearing in mild wet spells in winter and early spring and often associated with *Lycoperdon acuminatum*. The floeculent white mycelium penetrates the old bark and extends itself abundantly between the planes of cleavage. The species is distinguished from *G. coronatus*, which is nearest, by the much smaller average size, smaller and nearly white spores, and capillitium, and peculiar habitat. For the original description, see Bot. Gaz. **36**: 306. 1903.

681, 1085, 1479, 1537, 2028, 2029, 2466, 3222, 3231, 6052. All on mossy bark of living elm, hickory or cedar during winter or early spring.

Geaster pectinatus Persoon
G. multifidum var. α Pers.

PLATES 32 AND 35

Mycelium universal and forming a soft, floeculent coat that holds trash to the entire outer surface of the plant as in *G. rufescens;* rays

GEASTER LEPTOSPERMUS. No. 2466.

few to numerous, typically reflexed but the tips often incurved, central region concave below and elevating the spore sac; mycelial layer with attached earth tending to peel off after expansion as is also the brown fleshy layer, so that the thin, pale fibrous layer may be left almost naked in old specimens; spore sac subglobose to urn-shaped, with or without an apophysis, the lower part with radial lines or ridges that in some cases may be quite faint; stalk slender, typically rather long, up to 5 or 6 mm., often with a collar or ring near center or base; surface when fresh covered with a fine powder which is whitish against the spore sac and brown without so as to give the spore sac a whitish bloom where it is thin and a brown-drab color where it is thicker. Mouth long, narrowly conical, prettily sulcate-striate, brown.

Spores (of plant from Jamesville, N. Y.) very dark, with large blunt warts, 4.2-5.5μ thick. Capillitium threads up to 7μ thick.

A rare plant apparently, and Schweinitz's record is so far the only one from North Carolina. The length of stalk is very variable, e.g., in one good lot from Surrey, England, at the New York Botanical Garden Herbarium (as *G. limbatus*), the stalk is only 2 mm. long. The species runs into two extremes that are most conveniently treated as species, though intermediates occur. The smallest of these is *G. Schmidelii*, which also approaches *G. Smithii* (*G. ambiguus*, sense of Hollos). The other is *G. Bryantii* which is distinguished by a deflexed collar around the base of the spore sac. Specimens of *G. pectinatus* (Upsala) in the Curtis Herbarium are labelled *G. limbatus* by E. P. Fries.

A part of the type collection of *G. biplicatus* (Proc. Am. Acad. Arts and Sciences 4: 124. 1860) in the Curtis Herbarium (Bonin Isles) is so pressed as not to show the base of the spore sac; peristome truly sulcate; spore sac reddish brown with a grayish powder; outer surface covered with humus held by flocculence. Spores distinctly warted, 3.8-4.8μ, rarely up to 5.2μ thick. Other plants from the type collection in Washington are similar with inner peridium blackish brown with a grayish powder. We have a fine specimen from New Caledonia sent us by Patouillard (as *G. plicatus* = *G. biplicatus*) with strongly sulcate base to the spore sac, the stalk about 4 mm. long; spores spherical to a little irregular, distinctly warted, 4-6μ thick; capillitium straight, up to 6.5μ thick. It is probable that *G. plicatus* and *G. biplicatus* are the same, as Patouillard thinks, and

both are certainly very near *G. pectinatus*. The deep and regular sulcations on the base of the spore sac are a striking character that we have not seen exactly duplicated in *G. pectinatus*. We have seen Lloyd's abundant specimens of *G. plicatus* from Australia and South Africa, but have not seen the type.

Illustrations: Lloyd. The Geastrae, figs. 19-22 (fig. 19 was first published as *G. tenuipes* in Myc. Notes, p. 72, fig. 37).

Lloyd. Gen. Gastromycetes, pl. 8, fig. 38.

Petri. l.c., fig. 37, 4-5 and fig. 40.

Rick. Broteria **5**: pl. 1, figs. 14-15.

Schmidel. Icon. Plant., pl. 37, figs. 11-14. Edition of 1793. These are referred to by Persoon.

Scherffel. l.c., pl. 19, figs. 1, 2, and 4.

Smith. Grevillea **2**: pl. 17, fig. 1 (as *G. limbatus*). Ridges on mouth obscure.

North Carolina. Salem. (Schw. Herb.). Plant as large as usual in the species; stalk short and rather thick.

South Carolina. North Island. Under cedars. Coker and party, coll. (U. N. C. Herb.).

New York. Jamesville. Mrs. Goodrich, coll. (N. Y. Bot. Gard. Herb.).
Pompey. (N. Y. Bot. Gard. Herb., as *G. Bryantii*).

Ohio. (N. Y. Bot. Gard. Herb., from Lloyd Herb.).

Reported from Florida and Pennsylvania by Lloyd.

Ontario. Hamilton. Dearness, coll. (U. N. C. Herb.). Spores strongly warted, 4.5-6μ.

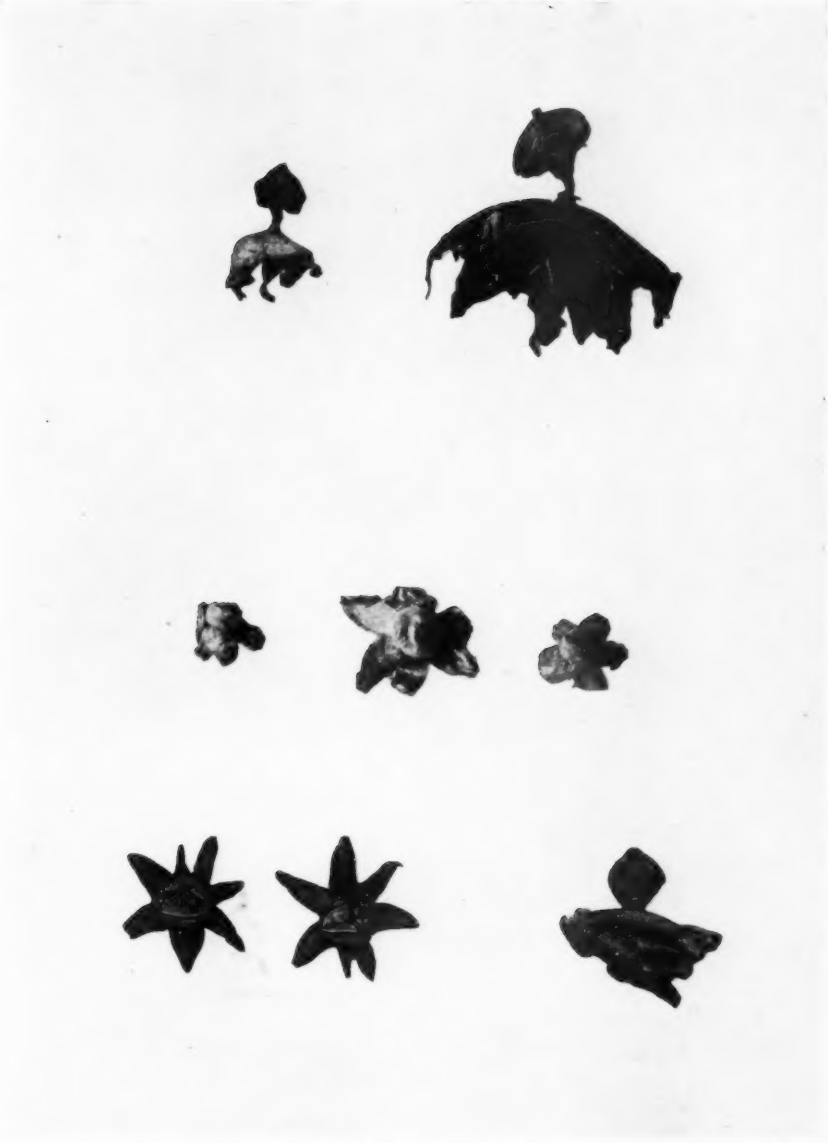
Geaster Bryantii Berk.

Like *G. pectinatus* except that around the base of the spore sac at some distance from the stem there hangs a collar-like ring with an acute edge. This character alone would hardly entitle the plant to more than varietal rank.

Spores of a plant from Massee (England [?], N. Y. Bot. Gard. Herb.) are spherical, distinctly warted, very dark, 4-5.5μ, most about 4.8μ. In another plant from Europe (Rabenhorst and Winter, Fungi europaei, No. 2639, N. Y. Bot. Gard. Herb.) the spores are smaller and less distinctly warted, 3.8-4.8μ thick. The plant is also well represented in Sydow's Mycotheca germanica, No. 1449 (Path. and Myc. Herb., Washington).

The plant is rare in America and is not reported from the southeastern states. Lloyd reports it from Maine and Texas, and Morgan from New York.

PLATE 32



[Top] GEASTER PECTINATUS. Small plant, London, Canada, No. 3023; larger plant, Webster's Falls, Canada, No. 4235.

[Middle] GEASTER SCHMIDELII. Newfield, N. J.

[Below] GEASTER UMBILICATUS. Newfield, N. J. [left].
GEASTER RABENHORSTII. Type material [right].

Illustrations: Berkeley. Grevillea 2: pl. 16, fig. 2.
Bryant. An Historical Account, etc., fig. 19. 1782.
De Toni. l.c., pl. 1, fig. D.
Hollos. l.c., pl. 9, figs. 1-4.
Lloyd. The Geastrae, figs. 23-26.
Massee. Ann. Bot. 4: pl. 4, fig. 56.
Morgan. North Amer. Geasters, fig. 5.
Rea. l.c., pl. 18.

Geaster Schmidelii Vitt.
G. Rabenhorstii Kunze

PLATES 32 AND 35

Like *G. pectinatus*, except smaller and with a short stalk and less separable mycelial layer and smaller spores. A typical lot of this form is No. 5020 of E. Bartholomew's Fungi Columbiana (Calloway, Nebraska; J. M. Bates, coll.). These have 5-6 reflexed rays with trashy mycelial layer attached, the thin brown fleshy layer also present; spore sac suboval, very short stalked, smooth, dark brown, mouth elevated, strongly sulcate. Spores medium dark, minutely warted, spherical, 3.7-4.4μ, with a visible oil drop.

Another lot of Bates's plants from Nebraska are in the New York Botanical Garden (from Lloyd Herb.). The outer surface is covered with sand, the spore sac blackish with a whitish or brown powder. A less typical lot is from New Jersey (Newfield; Earle, coll., at N. Y. Bot. Gard. Herb.). This lot has the rays slightly hygroscopic and in one of the plants the spore sac is yellowish buff color. Another plant of this lot is the one shown by Lloyd in his Geastrae, fig. 27a. The spores of this particular plant are like those noted above, minutely warted, 3.7-4.5μ. A plant about intermediate between *pectinatus* and *Schmidelii* is at the New York Botanical Garden Herbarium (Underwood, coll.; Kirkville, N. Y.). The spore sac is buffy and the stalk very short. European *G. Schmidelii* as distributed by Torrend (Mycotheca Lusitanica, in Path. and Myc. Herb., Washington) is like our American plant and like the types of *G. Rabenhorstii*. Three plants sent us for examination by Patouillard (Herb. Mus. Paris; Barla, coll.) as *G. Schmidelii* are somewhat worn specimens of the *minimus* form of *G. coronatus*. The spores are spherical, warted, 3.7-4.6μ.

Spores of the type material of *G. Rabenhorstii* (Fungi selecti exs., No. 10, in Path. and Myc. Herb., Washington) are spherical, distinctly warted, 3.8-5μ, a few up to 5.5μ. *Geaster elegans* Vitt. is very near *G. Schmidelii*, the only obvious difference being the entirely sessile spore sac and larger spores of the former. These characters are shown by plants in Torrend's Myeotheca Lusitanica, No. 78 (Univ. Wis. Herb. and U. N. C. Herb., as *G. elegans*), and in his Fungi selecta exs., No. 79 (in the same herbarium, as *G. minimus*); also in the Herbarium of the University of Paris (from Tulasne's Herb.). The spores of the last mentioned are minutely but distinctly rough. 4.2-5.5μ thick (pl. 36, fig. 2). The plant is not known from America.

This would seem to run into a saccate form, apparently quite sessile as shown by a distribution of 11 good plants by J. Kunze, Fungi selecti exs., as *G. striatus* DC., from the same place as his *G. Rabenhorstii* and also like that in growing in *Picea excelsa* needles; mouth, peridium and all else same except that the outer peridium is saccate or flat and inner peridium with no obvious stalk.

Illustrations: Destrée. l.c., pl. 7, fig. B.
Lloyd. As cited above.
Petri. l.c., fig. 37, 3.
Trelease. l.c., pl. 7, fig. 3 (as *G. Rabenhorstii*).
Vittadini. Monog. Lycoperd., pl. 1, fig. 7.

North Carolina. Salem. Schweinitz, coll. (Curtis Herb., as *G. pectinatus*). Spore sac practically sessile.

New Jersey. Newfield. Ellis, coll. (N. Y. Bot. Gard. Herb.).

Nebraska. Bates, coll. (N. Y. Bot. Gard. Herb., from Lloyd Herb. and Path. and Myc. Herb., Washington, as Bartholomew, Fungi Columb., No. 5020).

Texas. Denton. Long, coll. (Path. and Myc. Herb., Washington; Ellis and Everhart, Fungi Columb., No. 1620, as *G. pectinatus*). Mixed with these is a plant with strongly granular spore-sac like *G. asper* except that the outer peridium is not hygroscopic but like the others.

Cuba. Wright, No. 694. (Curtis Herb., as *G. tenuipes* Berk.). Spore sac apparently sessile, slate color with a dusting of grayish powder.

Geaster Hariotii Lloyd

PLATES 24 AND 35

Rays about 8, spreading about 3 cm., pliable, not hygroscopic, revolute or in part expanded, the center concave below and elevating the spore sac; outer surface entirely covered with earth or trash held on by flocculent mycelium which may in time be partially shed in

flakes. Fleshy layer dark brown, cracking and seceding in places. Spore sac 1.5 cm. broad, subglobose, sessile, dark brown to black, distinctly pitted and rough to asperate with small points, but not truly warted or tomentose. Peristome truly sulcate, mouth elevated and becoming fimbriate.

Spores (of plant from Porto Rico) spherical, dark, faintly rough under very high power, 3.5-4μ thick.

As Lloyd does not mention a rough surface to the peridium (Myc. Notes, p. 311) we had referred our plant to this species with some doubt until the recent receipt from Patouillard of a specimen from Brazil that had been seen by Lloyd and which Patouillard designates as an "original specimen." This is exactly like our plant except that the surface is somewhat less conspicuously rough; rays not rigid; spores spherical, nearly smooth, 3-3.6μ thick, often with a visible oil drop. Capillitium threads straight, encrusted, up to 6.5μ thick. Under *G. Archeri* Lloyd has two collections, one from Ceylon (Petch, coll.) and one from Victoria (Winkler, coll.). They are not that species, but pale forms of *G. Hariotii*. The mouth in each case is darker than the granular or spongy peridium; peridium clay-brown to brown; mouth truly sulcate; outer surface densely flocculent and with trash as in *G. Hariotii*.

Illustrations: Lloyd. Myc. Works, pl. 99, figs. 7-9.

Porto Rico. March, 1923. Seaver, coll. (Seaver Herb., No. 840, and U. N. C. Herb.).

British Honduras. M. E. Peck, coll. (N. Y. Bot. Gard. Herb.). Spores smooth, 3-3.7μ thick.

Brazil. (U. N. C. Herb. from Patouillard).

Rio. In leaf mold, March, 1894. Murrill, coll. (N. Y. Bot. Gard. Herb.).

Dutch Guiana. Samuels, coll. (N. Y. Bot. Gard. Herb.).

Geaster asper (Mich.) Lloyd.

G. pseudomammosus Henn.

G. campestris Morgan.

PLATES 24 AND 35

Plants submerged until mature, the mycelium universal; rays with a spread of 2.5-3.5 cm. (up to 5 cm., Morgan), hygroscopic, rigid, 8-10, rarely more, involute or spreading when dry, outer surface covered at first and rather persistently with sandy earth mixed with

flocculent mycelium, this slowly flaking off or wearing away on exposure, leaving the surface pale and smooth; fleshy layer adnate, usually continuous, dark brown to blackish; base concave below and elevating the spore sac which is subglobose with a short thickish stalk, the surface gray to brown and covered with wart-like particles; mouth strongly and prettily sulcate, seated in a depressed zone, concolorous or darker, at times nearly black.

Spores (of a plant from Lincoln, Nebraska), spherical, distinctly warted, 4.5-6.5μ. Capillitium threads straight, up to 5μ thick.

A plant of the Mississippi valley and westward, seeming to prefer sandy soil. It is well marked by the conspicuous granules on the spore sac, which are much coarser than the fine powdery particles on the sac of *G. coronatus* and *G. leptospermus*.

This species varies to a form with lax and pliable outer peridium like that of *G. mammosus* and *G. Schmidelii*. See, for example, one plant among a typical lot of *G. asper* from Dakota at Washington (Brenckle, Fungi Dakotensis, No. 35, in Path. and Myc. Herb.); also in the same herbarium a plant from Texas, mixed with *G. Schmidelii* (E. and E. Fungi Columb., No. 1620; Long, coll.).

Illustrations: Hollos. l.c., pl. 9, figs. 12-14, 21, 22; pl. 29, figs. 24, 25.
Lloyd. Myc. Notes No. 7: fig. 34; Geastrae, figs. 28-30.
Micheli. Nov. Plant. Gen., pl. 100, fig. 2.
Morgan. The Genus Geaster, fig. 1 (as *G. campestris*).
?Rick. Broteria 5: pl. 1, fig. 13 (as *G. asper*, but does not look much like ours).

Nebraska. Long Pine. Bates, coll.; Lincoln. Webber, coll. (N. Y. Bot. Gard. Herb. and U. N. C. Herb.).

North Dakota. Kulm, coll. (N. Y. Bot. Gard. Herb. and U. N. C. Herb., as Sydow, Fungi exot., No. 151).

Kansas. Bartholomew, coll. (Path. and Myc. Herb.). In this lot the mouth is nearly black, contrasting strongly with the nearly white peridium.

Utah. Fort Douglas. Clements, coll. (Farlow Herb.). Granules on spore sac inconspicuous, but appearance and spores as in *G. asper*. Spores spherical, irregularly warted, 4.4-5.5μ rarely up to 6μ thick.

Texas. Denton. Long, coll. (E. and E. Fungi Columb., No. 1825. Path. and Myc. Herb., as *G. striatus*).

Geaster umbilicatus Fr. Sense of Morgan.
G. striatulus Kalch. Sense of Lloyd.
? *G. Smithii* Lloyd.
G. ambiguus Mont. Sense of Hollos in part.

PLATES 32 AND 35

Plants small, hygroscopic, the button subterranean and when first expanded covered completely without by sandy earth; rays about 7-10, unequal in breadth, the delicate, flocculent outer layer intimately mixed with earth and gradually wearing away to leave the rays smooth and glabrous and pale brown to pallid tan, scarcely shining and not as metallic-looking as in *G. mammosus;* fleshy layer rather thin, smooth or more or less rimose, brown to blackish. Spore sac 7-12 mm. thick, sessile, pale tan to dark brown, minutely furfuraceous until old; peristome prettily and regularly plicate-sulcate, strongly furfuraceous, particularly below, when fresh, the mouth usually elevated and conical or at times flattened in a depressed zone.

Spores (of plants from New Jersey, Ellis, No. 3472) spherical, faintly warted, 3.5-4μ thick. Capillitium threads wavy, up to 6.5μ thick.

A plant of sandy soil in Europe and America and evidently rare. It is the plant distributed by Ellis as No. 110 in his North American Fungi (as *G. mammosus*), and a letter to Ellis from Morgan at the New York Botanical Garden states this to be the same as his *umbilicatus.* The species is known from New Jersey (Ellis) and from Florida (Lloyd), and, so far as can be seen from the description and the figure, Morgan was right in thinking it the same as *G. Smithii* Lloyd (Geastrae, p. 21). It should certainly occur on our North Carolina coast.

The rays in this species while distinctly hygroscopic are more delicate and pliable than in *G. mammosus* and much more so than in *Astraeus.* From *G. Drummondii (G. involutus)* and *G. asper* the plant is easily separated by the delicately and softly furfuraceous, not warted or asperulate spore sac, and by the smaller spores. From *G. Schmidelii,* which is very near, it is separated by its hygroscopic and not revolute rays and by the sessile spore sac. The spores of the two are very nearly alike. Lloyd has seen the type of *G. ambiguus* and thinks it different from *G. striatulus,* to which he refers the present plant (Myc. Notes, p. 311).

Geastrum minimum Chev. (Fl. Gen. Env. Paris 1: 360, pl. 10, fig. 3. 1826) does not look much like this species. It has a distinct, slender stalk, though short, and that is why Chevallier considered it new. He gives the sessile *G. badium* Persoon under his species as a form *alpha*. Hollos considers *G. badium* and *G. umbilicatus* the same as *G. elegans* Vitt. (which we see under *G. Schmidelii*). From the description there is no reason to think that *G. striatus* var. *minimus* Wallroth (Fl. Crypt. Germaniae 2: 400 (No. 2274) is the same as our American plant above described. He refers to Chevallier's *G. minimum* as the same.

Illustrations: Hollos. l.c., pl. 9, figs. 15-17 (as *G. ambiguus*).
Lloyd. Myc. Notes, p. 71 (as *G. striatulus*). Also copied on pl. 98, figs. 3, 4.
Morgan. North Amer. Geasters, fig. 4.

Florida. Mrs. Sams, coll. (Lloyd Herb., as *G. Smithii*).

New Jersey. Newfield. Ellis. (N. Am. Fungi, No. 110. Also several other collections by Ellis at the N. Y. Bot. Gard. Herb., as *mammosus* or *umbilicatus*).

Geaster Drummondii Berk.

G. involutus Massee.

G. Schweinfurthii Hennings.

PLATES 35 AND 36

At the New York Botanical Garden Herbarium are two good plants from Brisbane, Australia (Herb. Massee) which appear to truly represent this species. The plants are:

Hygroscopic, rigid; fleshy layer blackish; outer surface covered with sandy humus; spore sac small, subglobose, sessile.

One plant has the inner peridium 12 mm. broad, spiny-granular; mouth blackish, 12-ridged. Spores faintly rough, spherical, 5.4-6.5μ.

The other has the inner peridium 9.5 mm. broad, pulverulent-granular; mouth creamy gray, 19-ridged. Spores faintly rough, 4.5-6.5μ.

Inner peridium of both creamy gray (pale leather color).

Type plants of *G. involutus* from St. Domingo at the New York Botanical Garden show that no important difference can be made out to distinguish it from *G. Drummondii*. The appearance is identically like that of the plant with spiny peridium, except that the mouth is not dark. The spores are the same, minutely warted, 4-5μ thick. The

inner peridium is asperate and the mouth beautifully sulcate with 12 or 14 ridges. Hollos gives *G. avellaneus* Kalch. as a synonym of this species, and both as synonyms of *G. ambiguus* Mont. The former was published only as a figure, with no written description. The spore sac is shown as white and not dotted; the outer peridium evidently hygroscopic, in one case folded over the spore sac, its outer surface ochraceous with some earth attached; mouth truly sulcate.

Illustrations: Berkeley. Journal of Bot. for 1845, pl. 1, fig. 4.
Hennings. Engler's Bot. Jahrb. **14**: pl. 6, fig. 7.
Lloyd. Lycop. of Australia, etc., fig. 8 (types of *G. Drummondii*).

St. Domingo. Part of type of *G. involutus* at N. Y. Bot. Gard. Herb.

Australia. Victoria. (Kew Herb., as *G. argentatus*).

ASTRAEUS

This genus, formerly included in *Geaster* and of the same general appearance, was established by Morgan on the following essential differences: chambers of the gleba stuffed with the hymenial tissue as in *Scleroderma;* threads of the capillitium long, much branched and interwoven, scarcely different from the elemental hyphae of the peridium and continuous with them, in these respects agreeing with *Tylostoma;* columella entirely absent; spores much larger than in any *Geaster*. The hygroscopic character of the rays is very marked, as is their hard and woody texture when dry. There is but one species known.

Astraeus hygrometricus (Pers.) Morg.
Geaster hygrometricus Pers.
Geastrum fibrillosum Schw.
Geaster stellatus Scop.
Astraeus stellatus (Scop.) Fisch.

PLATES 33 AND 35

Plants of small to medium size, growing just beneath the soil and covered all over by a thin mycelium which tears as the rays expand. Outer peridium thick and composed of two distinct layers, the outer fibrous-leathery-looking, the inner subtranslucent and of the appearance of horn or cartilage; at maturity splitting into six to many rays which expand or recurve when wet and fold in again when dry, the

inner layer soon becoming much cracked. Inner peridium pliable, thin, sessile, depressed-globose, about 1.2-3 cm. broad, reticulated with fibrous lines when in good condition, whitish, becoming gray or brownish, opening by an irregularly torn mouth which is without a defined peristome.

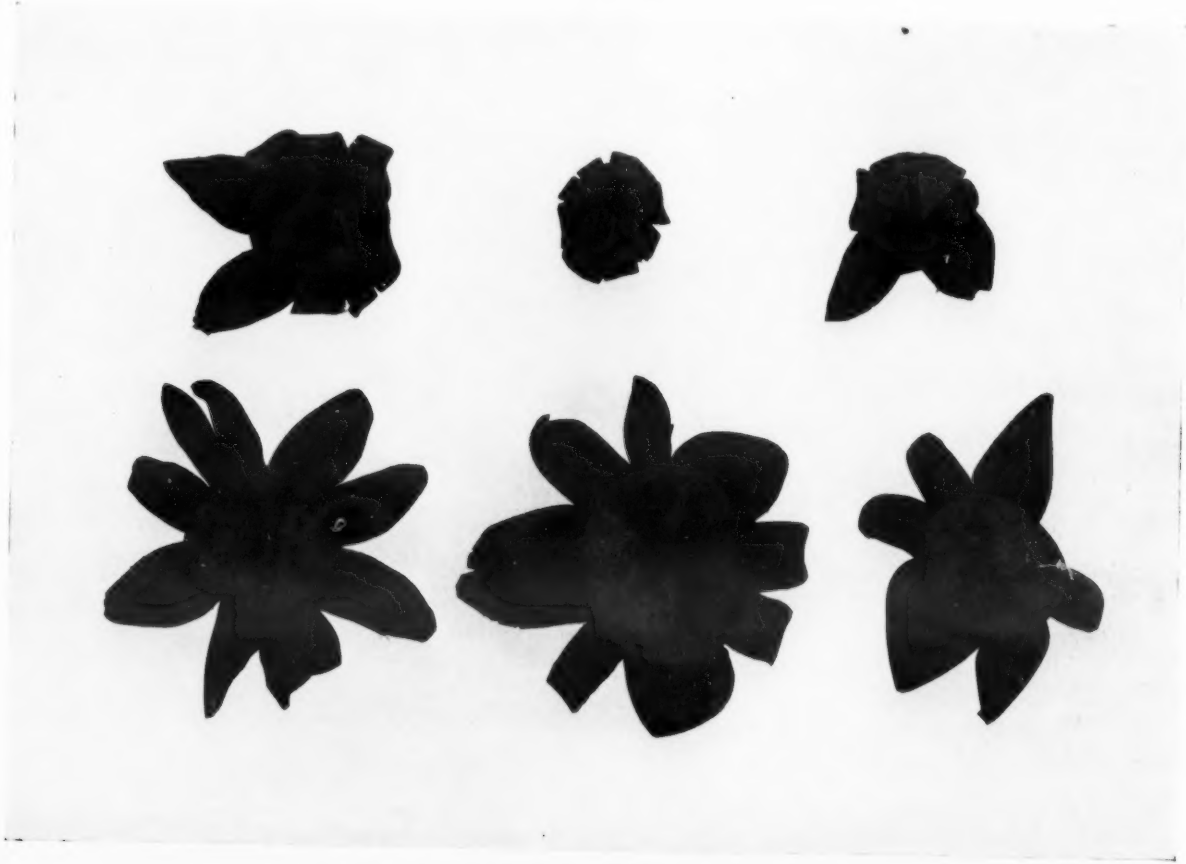
Spores (of No. 685) reddish brown, globose, distinctly tuberculate, 7.4-10.8μ thick, including the warts. Capillitium threads very pale, long, interwoven, branched, 3-5.5μ thick, smooth or encrusted with granules.

This interesting species is of world wide distribution and we have seen plants from many states of the Union. The plant is very persistent. Ripening in the fall, it may be found in good condition through the winter. Like many Geasters it is loosened from the soil on expanding and may be rolled about by the wind when dry. We have examined the type of *Geastrum fibrillosum* in the Schweinitz Herbarium, and find that it is, as Lloyd says (Geastrae, p. 10), a condition of the present species. The spores are roughened, 7.4-10μ thick.

Lycoperdon recolligens Woodward (Trans. Linn. Soc. **2**: 58. 1794) seems to include both the present species and *G. mammosus*. He refers to Schmidel's plates 27 and 28 which are the former.

Illustrations: Bigeard. Flore des Champ. **1**: pl. 49, fig. 2. 1909.
Cordier. Champ. Fr., pl. 56, fig. 1.
Destrée. l.c., pl. 10, fig. B.
De Toni. l.c., pl. 62, fig. E.
Hard. Mushrooms, fig. 483.
Hollos. l.c., pl. 10, figs. 26-29.
Leuba. Les Champignons, etc., pl. 51, figs. 1-7. 1887-90.
Marshall. Mushroom Book, pl. opposite p. 130.
Michael. Führer f. Pilzfreunde **2**: No. 204. 1918 (2nd. ed.)
Micheli. Nova Plant. Gen., pl. 100, fig. 6.
Morgan. Journ. Cin. Soc. Nat. Hist. **12**: pl. 2, figs. 8-11 and Amer. Nat. **18**: fig. 12.
Nees von Esenbeck. Syst. Pilze Schw., pl. 12, fig. 127.
Petri. Flora Italica Cryptogama (Gasterales), Fasc. **5**: figs. 80-82. 1909.
Rea. l.c., pl. 17.
Schmidel. Icon. Plant., pls. 27 and 28, figs. 19-31 (as *Geaster astraeus*). 1793.
Vittadini. Monog. Lycoperd., pl. 1, fig. 8. 1842.

73. Mixed woods with cedars on hill east of Tenney's, October 11, 1911.
673, 685. Old collections (Chapel Hill). No data.



ASTRAEUS HYGROMETRICUS. Smith's Island [4 large plants].
No. 685 [middle plant above]; No. 73 [right above].

7237. Underground in open, sandy field, January 14, 1923.
Wilmington. (Curtis Herb.).
Smith Island. Couch and Grant, No. 3007. Sandy soil, April, 1918. Spores 7.7-9.3μ, warted.
Little Switzerland. Miss Osborne, No. 2272a. October, 1916.
Blowing Rock. Coker and party, August, 1922. Nos. 5786 and 5823.
Asheville. Beardslee.
Pink Bed Valley. Murrill and House, No. 400. July, 1908. (N. Y. Bot. Gard. Herb.).

South Carolina. Ravenel. Fung. Car. Exs. No. 75 (Philadelphia Academy).
North Island. Coker and party, colls. (U. N. C. Herb.). Very plentiful among the sand dunes.

Massachusetts, Illinois, South Carolina, Texas, California, Japan. (All in Curtis Herb.). Also from a number of other states in different herbaria.

CHAPEL HILL, N. C.

EXPLANATION OF PLATES

PLATE 35

Geaster triplex. No. 682, fig. 1 (lower spore drawn in 7 per cent KOH).
Geaster limbatus, sense of Bresadola. Burlington, Wisconsin, fig. 2.
Geaster limbatus, sense of Hollos. England (?) (Massee; N. Y. Bot. Gard. Herb.), fig. 3.
Geaster Morganii. Ohio (Underwood; N. Y. Bot. Gard. Herb.), fig. 4.
Geaster saccatus. Asheville, N. C., fig. 5; New Haven Gap, Jamaica, fig. 6.
Geaster velutinus. No. 4095, fig. 7.
Geaster Readeri. Type, fig. 8.
Geaster radicans. Co-type (Ravenel, No. 953), fig. 9.
Geaster mirabilis. No. 7077, fig. 10.
Geaster papyraceus. Kiu Siu, Japan (Curtis Herb.), fig. 11.
Geaster caespitosus. Ohio (Lloyd; N. Y. Bot. Gard. Herb.), fig. 12.
Geaster limbatus, sense of Hollos. England (?) (Massee; N. Y. Bot. Gard. Herb.), fig. 3.
Geaster subiculosus. Jamaica (Earle, No. 184), fig. 14.
Geaster mammosus. Canada, fig. 15.
Geaster arenarius. Florida (Lloyd), fig. 16.
Geaster rufescens. No. 985, fig. 17.
Geaster fornicatus. Smith's Island, N. C., fig. 18.
Geaster fimbriatus. No. 7097, fig. 19.
Geaster floriformis. Colorado (Clements, No. 613), fig. 20.
Geaster coronatus. No. 75, fig. 21; No. 684, fig. 22; No. 3881, fig. 23.
Geaster minimus. Type, fig. 24.
Geaster Cesatii. No. 1634 (Cesati; Path. and Myc. Herb.), fig. 25.
Geaster leptospermus. No. 2028, fig. 26.
Geaster pectinatus. Jamesville, N. Y., fig. 27.
Geaster plicatus. France (Patouillard), fig. 28.
Geaster biplicatus. Bonin Islands (co-type), fig. 29.
Geaster Bryantii. England (?) (Massee; N. Y. Bot. Gard. Herb.), fig. 30.
Geaster Schmidelii. Calloway, Nebraska (Bartholomew, No. 5020), fig. 31.
Geaster Rabenhorstii. Type distribution, fig. 32.
Geaster Hariotii. Brazil (Herb. Patouillard), fig. 33.
Geaster asper. Lincoln, Nebraska, fig. 34.
Geaster umbilicatus. Newfield, N. J., (Ellis), fig. 35.
Geaster Drummondii. Brisbane, Australia, fig. 36.
Astraeus hygrometricus. No. 685, fig. 37.
All figures x 1620.

PLATE 36

Geaster limbatus, sense of Bresadola. Kansas (Bartholomew, coll.), No. 8252, fig. 1.
Geaster elegans. France (?), Herbarium of Tulasne, fig. 2.
Geaster radicans. Sarasota, Florida, fig. 3.
Geaster caespitosus. Type, fig. 4.
Geaster arenarius. Type, fig. 5.
Geaster mammosus. North Dakota (Brenckle, coll.), No. 254, fig. 6.
Geaster subiculosus. Type, fig. 7.
Geaster lignicola. Type, fig. 8.
Geaster Hieronymi. Jalapa, Mexico (Murrill, coll.), No. 244, fig. 9.
Geaster floriformis. North Dakota (Brenckle, coll.; Sydow, Fungi exot. exs., No. 152), fig. 10.
Geaster calceus. Type, fig. 11.
Geaster granulosus. Austria (Fuckel, coll.), fig. 12.
Geaster argenteus. Type, fig. 13.
Geaster Archeri. Type, fig. 14.
Coilomyces Schweinitzii. Co-type, fig. 15.
Geaster terreus. Waste Lands, South Dakota, fig. 16.
Geaster argentatus. Type, fig. 17.
Geaster coronatus. No. 6065 (fornicate form), fig. 18; Ymala, Mexico (*minimus* form), fig. 19.
Geaster involutus. Type, fig. 20.
All figures x 1620.

INDEX TO SCIENTIFIC NAMES REFERRED TO IN THIS ARTICLE

Astraeus, 175, **219**
hygrometricus, **219**
stellatus, 219
Coilomyces Schweinitzii, 190
Geaster, **170**, 219
ambiguus, 211, 217, 219
Archeri, 181, 215
arenarius, 172, 174, **195**
arenarius, a form, 175
argentatus, 194
argenteus, 193, 194
asper, 172, 175, 204, **215**, 217
australis, 185
avellaneus, 219
badium, 218
biplicatus, 211
Bryantii, 175, 207, 211, **212**
caespitosus, 188, 190
calceus, 207
campestris, 215
Cesatii, 205, 207
corallinus, 193
coronatus, 175, 195, 200, **205**, 210, 216
Curtisii, 186, 187
delicatus, 203, 204
Drummondii, 172, 175, 194, 217, **218**
elegans, 214, 218
fimbriatus, 175, 183, 195, 198, **200**
floriformis, 172, 175, 194, 196, **203**
fornicatus, 171, 174, **199**, 206
granulosus, 207
Hariotii, 172, 175, **214**
Hieronymi, 174, **198**
hygrometricus, 219
involutus, 218
lageniformis, 176, 183, 202

leptospermus, 175, **209**, 216
lignicola, 188, 190
limbatus, 174, **178**, 197, 211
lugubris, 193
mammosus, 174, **193**, 216, 220
marginatus, 205
Michelianus, 176
minimus, 171, 205, 206, 207
mirabilis, 174, **188**, 191, 192
Morganii, 172, 173, 174, **181**
multifidum var, α, 210
papyraceus, 189
pectinatus, 175, 179, **210**, 212, 213
plicatus, 211, 212
pseudo-limbatus, 180
pseudomammosus, 215
quadrifidum, 205
Rabenhorstii, 213, 214
radicans, 171, 174, **186**
Readeri, 185
rufescens, 174, 179, 180, **196**, 198, 200, 202
saccatus, 174, **182**, 188, 201
Schmidelii, 175, 211, 213, 216, 217
Schweinfurthii, 218
Smithii, 211, 217
stellatus, 219
striatulus, 217
striatus, 214
striatus var, minimus, 218
subiculosus, 173, 174, 189, **191**
terreus, 207
trichifer, 174, 189, **191**
triplex, 173, **176**, 179, 181, 183
tunicatus, 200, 202
umbilicatus, 175, **217**
velutinus, 174, 183, **185**, 186, 187
Welwitschii, 187

Geastrum fibrillosum, 219, 220
minimum, 218

Lycoperdon acuminatum, 210
leprosum, 185
pusio, 192
recolligens, 220

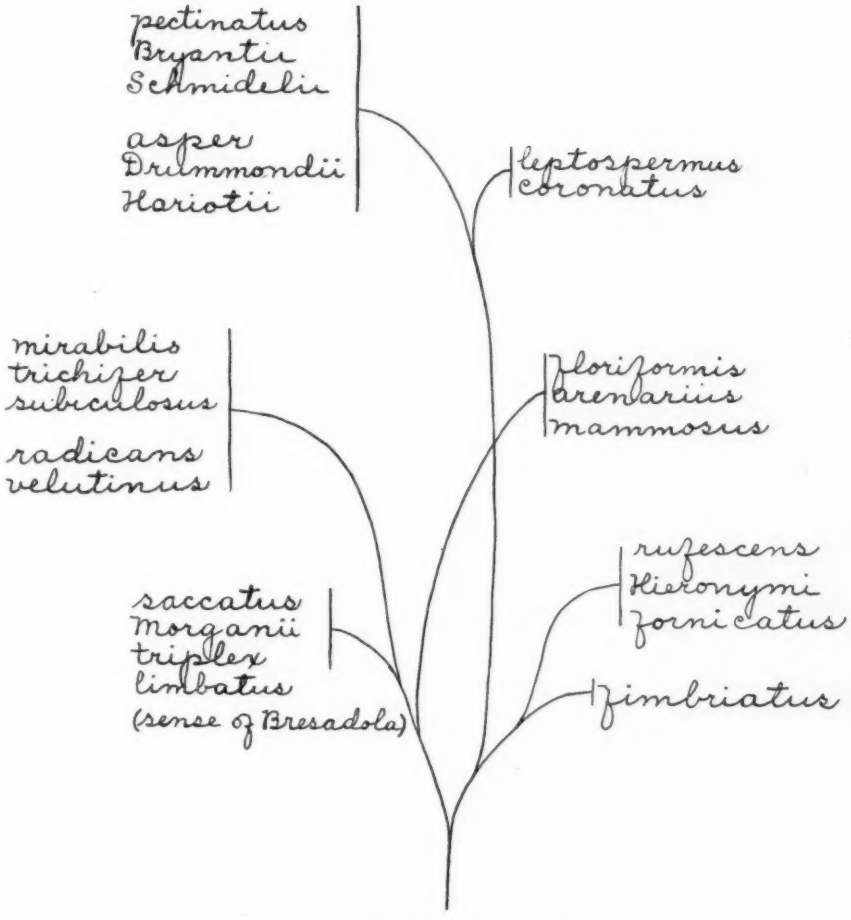
Myriostoma, 171

Scleroderma, 219

Trichaster melanocephalus, 171

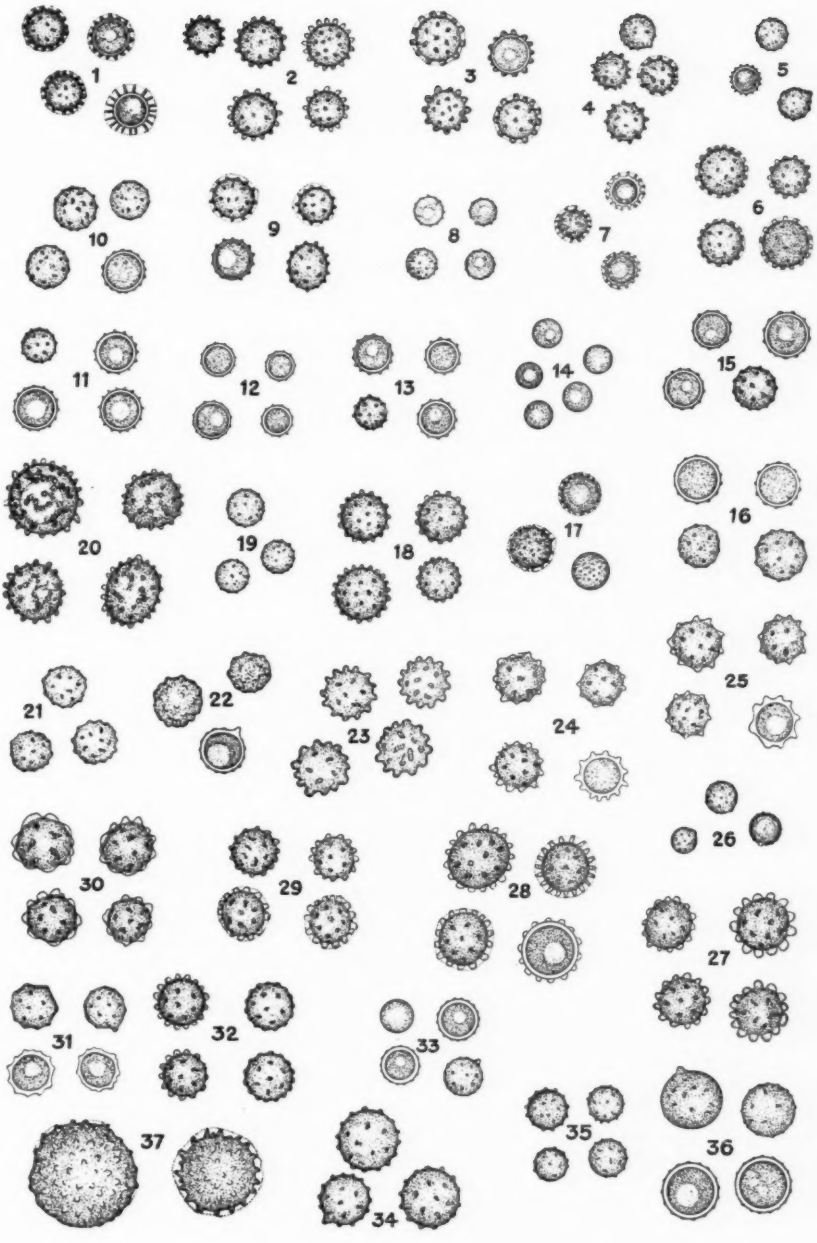
Tylostoma, 219

PLATE 34



Suggested relationships of the Geasters.

PLATE 35


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37

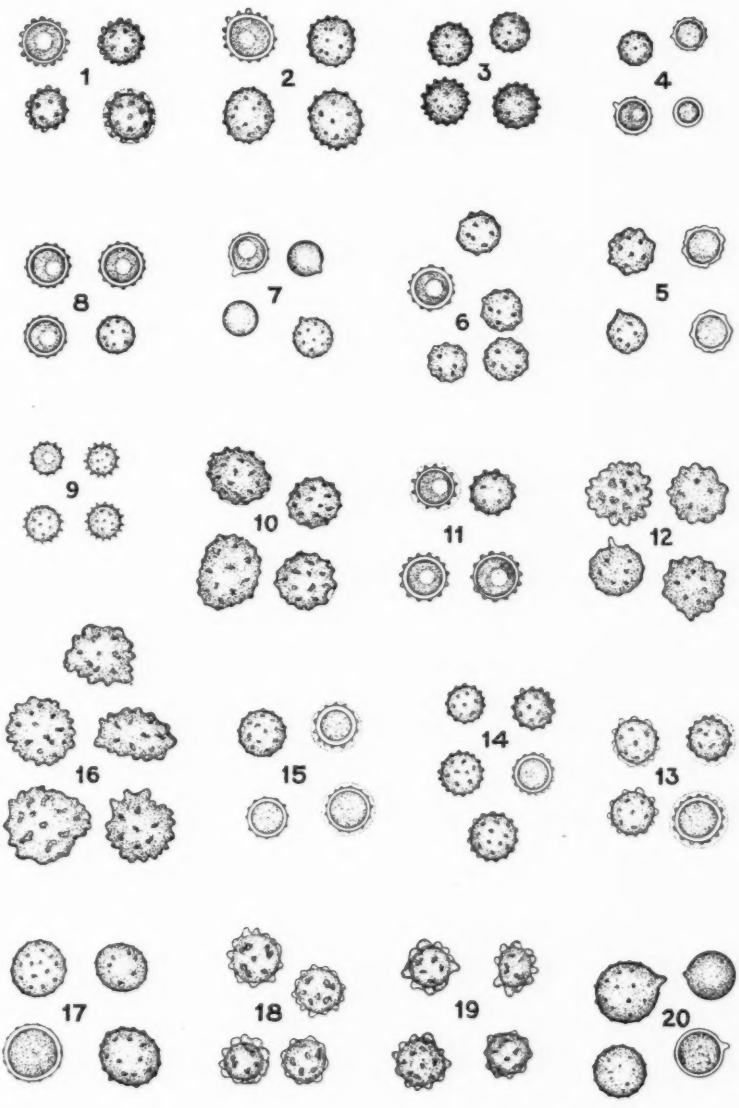



PLATE 36